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THE PRACTICAL ASPECTS OF THE PROPAGATION OF HIGH-FREQUENCY ELECTRIC WAVES ALONG WIRES.*

BY

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A NEW art has been born to us. The infant art of high-frequency multiplex telephony and telegraphy is the latest addition to our brood of young electric arts. It is certainly a most promising youngster and should, after the manner of its kind, call lustily for its share of attention and sustenance.

More than twenty years ago the advent of this new art was definitely prophesied by the late J. W. Gibboney [1] and the author [2] in this country, and in France by the well-known electrical engineers Maurice Hutin and Maurice Leblanc. But though there was at that time a vigorous contest for priority which extended over a period of years, it is not with these early records, prophetic though they be, that we have to deal now. They are buried in the archives of the United States Patent Office. Our interest to-day is in the vital practical aspects of the new art, based upon the

* Communicated by the author.

[1] U. S. Patent No. 481,529, telephony, application filed Feb. 8, 1892, patent granted Aug. 23, 1892.

[2] Interference in the U. S. Patent Office No. 17,197, Stone *v.* Hutin & Leblanc, subject multiple telephony. Record for Stone and record for Hutin & Leblanc.

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propagation of high-frequency electric waves along wires, and certainly, though twenty years ago there seemed to be much promise of the new art, there were, indeed, surprisingly few practical aspects to the subject.

For the past three years or more Major Geo. O. Squier, of the Signal Corps of the United States Army, has conducted a systematic investigation of the propagation of high-frequency electric waves along wires and of the practicability of their use in the transmission of signals and of speech along actual telephone cables and air lines. His investigations have also dealt with electrical resonance as a means of segregating, at the receiving end of the line, high-frequency currents of different frequencies simultaneously propagated along the line, and the selective reception of the energies of these different currents, each in a different receiver circuit made responsive only to the variations in the amplitude or strength of the current it is resonantly tuned to receive. The results of his labors are to demonstrate beyond a peradventure that not only Morse signals but speech may be transmitted over the ordinary telephone cable and pole line circuits and to very considerable distances by means of high-frequency electric currents or waves, and that a large number of telegraphic or telephonic messages may thus be transmitted simultaneously over a given telephone or telegraph circuit without interfering with each other through the use of electrically tuned or electrically resonant receivers. Moreover, he has shown that the new high-frequency multiplex telegraph and telephone system may be superimposed on the older systems or the new high-frequency apparatus added to lines equipped with the usual telegraph or telephone apparatus without interfering in any way with the operation of this older apparatus or being interfered with by it.[3]

Major Squier has dedicated to the public his patents relating to this new art—an act which, though laudable in the spirit it displays, is nevertheless unfortunate, as it is more likely to retard the progress of the new art than to advance it, since what is everybody's business is nobody's business, and capital may hesitate to enter a new field and promote an undertaking in which it is led

[3] Paper by Geo. O. Squier in the *Proceedings A.I.E.E., May*, 1911. U. S. Patents to Geo. O. Squier, Nos. 980,356, 980,357, 980,358, 980,359, all granted Jan. 23, 1911, and all dedicated to the public.

to believe that it will meet with unrestricted competition as the reward for its enterprise.

The frequencies of the electric waves or currents propagated along the wires in this new art are, so to speak, "above the limit of audibility of the receivers" or are ultra-sound frequencies. In other words, each of the electric currents propagated along the telegraph or telephone line is of so high a frequency that it can produce no audible effect in the telephone receiver through which it passes as long as its strength or amplitude remains constant. In fact, the frequencies of the currents used in this new telegraphy and telephony are 20,000 or more alternations per second, and correspond, therefore, to the frequencies of the air vibrations of sounds whose pitches are above the limit of audibility of the human ear. In the new telegraphy and telephony, the telegraphic signals and the voice are transmitted over the line wire by suitable variations in the amplitude or strength of the otherwise uniform high-frequency current, and the signals and the voice are received in a magneto telephone receiver connected in a local circuit which included a device capable of rectifying the high-frequency current used. The rectifier employed is preferably an Audion,[4] though a Wollaston[5] electrode and perhaps other radio-telegraphic detectors, particularly the so-called crystal rectifiers, may also prove serviceable.

The rectifier in the local circuit at the receiver converts the high-frequency current of the line wire into a pulsating current of double the frequency, or, what is the same thing, it converts the high-frequency current into a normally uniform unidirectional current with a superimposed alternating current of double the frequency of the line current. The telephone receiver is mute to the alternating component of the rectified current, but responds to the most minute variations in the strength of the unidirectional component of this current. Variations in the amplitude or strength of the high-frequency line current are faithfully reproduced in

[4] *Proc. Inst. Elect. Eng.*, xxv, pp. 219–247, 1906.
Elect. World, xlviii, p. 1109, 1906.
Ibid., xlviii, p. 1186, 1906.
U. S. Patent No. 879,532 of 1908 to de Forest, and U. S. Patent No. 884,110 of April 7, 1908, to J. S. Stone and S. Cobat.

[5] Paper by Dr. Wm. H. Wollaston, *Phil. Trans. of the Royal Soc. of London*, vol. 91, part ii, pp. 430–432, published 1801.

the strength of the unidirectional component of the local receiver current, and in this way the telephone receiver is made highly sensitive to variations in the strength of the high-frequency line currents, while absolutely mute to that current when its amplitude is constant.

However much the lack of a definite ownership and consequent lack of definite financial backing may militate against the rapid commercial adoption and extension of the new art, there can be little doubt that the actual transmitting and receiving apparatus of either the high-frequency multiplex telegraph or telephone will receive ample attention on the part of inventors and engineers. This apparatus is destined to be and is even now being perfected in its every detail, for the reason that the transmitting and receiving apparatus of the new multiplex telegraph and telephone is identical with that of the new continuous wave train radio-telegraph and radio-telephone respectively. We have here no mere analogy or similarity; it is an identity. Thus a number of continuous wave train radio-telegraphic transmitters connected to a telegraph line and an equal number of radio-telegraphic receivers similarly connected to the line actually constitute one of the new high-frequency multiplex telegraph systems, and correspondingly one of the new multiplex telephone systems may be constructed by attaching a number of radio-telephonic transmitters and an equal number of radio-telephonic receivers to a telephone circuit.

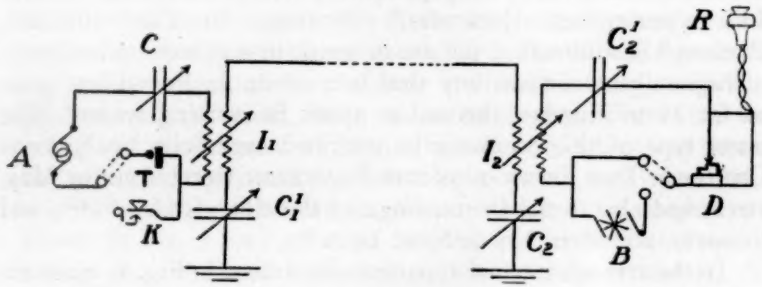
Of course, the perfection of the transmitter and receiver is by no means all or even the most important practical desideratum in the evolution of the new art. For the realization of the great economies this art seems destined to effect in the cost of telegraph and telephone circuits, much will have to be done in the way of adapting the new system to the complex existing and future telephonic exchanges, their mechanisms and net-works of circuits. In its application to the existing telegraph systems less difficult problems will in general have to be met, but even in the application of the new multiplex telegraph to one of the simplest existing telegraph installations it is more than probable that some unforeseen conditions will arise to meet which will require the exercise of some ingenuity and skill.

The relation of the new high-frequency telegraph and telephone to radio-telegraphy and radio-telephony is to be readily

seen in Fig. 1, which illustrates the new system in its simplest practical form. The diagram shows, in fact, two radio-telegraph or radio-telephone stations with a connecting wire between them to guide the waves from the transmitter to the receiver.

In this arrangement the current is supplied by a high-frequency alternating current dynamo *A*, which must be capable of supplying 20 watts at 10 volts and at not less than 20,000 cycles per second. These requirements are more than met in the Alexanderson high-frequency dynamo,[6] which has already been constructed to a capacity of at least 2 kilowatts and develops at its

FIG. 1.



highest speed currents of 100,000 cycles per second. In the case of high-frequency telephony this dynamo has to meet a further requirement which is not demanded of it by high-frequency telegraphy, and this requirement is perhaps the most difficult one to satisfy. It is that the amplitude of the current the dynamo supplies must be absolutely smooth and can have no variations or ripples on it of periods corresponding to the periods of audible tones. In this connection the author noted that a 2 kilowatt Alexanderson dynamo gave a loud musical tone in the telephone at the receiving end of the line when the dynamo was worked with the normal separation between the stator and rotar, and he found it necessary to increase the air gap to a point at which the capacity of the dynamo was about one-eighth of its normal rated capacity before a quiet line was secured. Even at this adjustment, however, the dynamo had more than ten times the required capacity.

[6] *Trans. Am. Inst. Elect. Eng.*, vol. xxviii, p. 399.

Owing to the small amount of energy required of the dynamo, there is no particular difficulty in constructing machines to meet the demands, very unusual though they be, particularly in the case of high-frequency telephony. It is not likely, however, that high-frequency dynamos will long be used in this connection, because oscillators giving sustained oscillations or continuous trains of waves of ultra-sound frequencies, constructed on the general principle of the Elihu Thomson oscillator,[7] are very much cheaper and less cumbersome than the dynamo, while requiring less care and skill in their operation. The early Thomson oscillator has been considerably improved, particularly through the use, for uniform cooling of the spark or arc gap, of various devices, such as massive and water-cooled electrodes.[8] Working in this direction, Paulsen [9] has immersed the arc or spark in a gaseous atmosphere of higher heat conductivity than air, while de Forest has gone so far as to immerse the arc or spark in running water. The latest type of this oscillator is described very fully by E. Leon Chaffee in THE JOURNAL OF THE FRANKLIN INSTITUTE for May, 1912, and also in the *Proceedings of the Am. Acad. of Arts and Sciences,* vol. xlvii, No. 9, Nov., 1911.[10]

In the arrangement of apparatus illustrated in Fig. 1, when the switches at the transmitter and at the receiver are both thrown up as shown, the arrangement is a high-frequency telephone system, while when the switches are both thrown to their lower contact points the arrangement becomes a high-frequency telegraph system, so that the one diagram may be used to sketch the operation and requirements of both the new telegraph and the new telephone.

In the new telephone system, when the transmitter T is spoken to, it modifies the amplitude of the high-frequency current in the primary circuit of the induction coil I_1 in exactly the same way that it modifies the strength of the battery current in the primary circuit of the induction coil in the old telephone system, and, as already described, the telephone receiver R at the receiving station responds, owing to the fact that exactly corresponding fluctuations

[7] U. S. Patent to Elihu Thomson, No. 500,630, of July, 1892.

[8] U. S. Patents to J. S. Stone, Nos. 767,983 and 803,199.

[9] U. S. Patent to V. Paulsen, No. 789,449.

[10] A further improvement in this oscillator is described in U. S. Patents to J. S. Stone, No. 802,431 of 1905 and No. 946,167 of 1910.

result in the unidirectional component of the rectified current in the local circuit at that station.

In the new telegraph system the operation of the telegraph key K, to send Morse signals, alternately throws the high-frequency current on the line and cuts off the supply of this current from the line. The result of this would be only to make successive faint clicks in the telephone receiver R as the current is thrown on and off, except for the periodic interrupter B, which may be of the nature of a revolving commutator or a mere buzzer. This interrupter serves to break the incoming wave trains constituting the Morse signal elements up into a succession of much shorter wave trains having a frequency of about 450 impulses per second, which when rectified give rise in the telephone receiver to a high pitched musical tone of great audibility. The Morse signals now are audible as a succession of long and short intervals of a high-pitched musical sound, as in radio-telegraphy. From the foregoing and the diagram of Fig. 1 the essential differences between the new telegraphy and the new telephony will easily be seen.

Some of the more essential characteristics of the simple system shown in Fig. 1 may prove of interest, particularly as they have not as yet, so far as I am aware, been clearly set forth. The induction coils I_1 and I_2 are wound without any iron in their cores, since in the first place the presence of iron is not needed to secure a large mutual inductance between the primary and the secondary circuits, because a high degree of coupling [11] between these circuits is not desirable, and, in the second place, the presence of iron in the core of the coils would introduce a loss of energy, through hysteresis, owing to the high frequencies used, which would give rise to an effect equivalent to the presence of a considerable dissipative resistance in the primary and in the secondary circuits. The arrow through the symbols for the coils indicates that these coils are adjustable with respect to their degree of coupling in the same way and for the same reason that the coupling of the corresponding coils is made adjustable in radio-telegraphy and radio-telephony. Similarly, the arrows through the symbols

[11] The coupling coefficient of the induction coil is $\frac{M}{\sqrt{L_1 L_2}}$, where M is the mutual inductance, and L_1 and L_2 are the inductance of the primary and secondary coils respectively.

for the condensers $C_1C'_1C_2$ and C'_2 indicate that these condensers are of adjustable capacity.

The function of the variable condensers at the transmitting and receiving stations is to electrically "tune" these stations. In the transmitting station of the system shown in Fig. 1, the so-called tuning is quite different in the case of the telephone and telegraph systems. In the case of the telegraph, the coupling of the coil I_1 and the capacities of both condensers at the transmitter are adjusted with reference to the production of a maximum current in the line wire, as indicated by a hot wire ammeter connected in the secondary circuit.[12] In the case of the telephone system, the coupling of the coil I_1 is made very small, and each of the condensers at the transmitting station is then independently adjusted to make the current in the circuit in which it is included a maximum, as indicated by hot wire ammeters connected in each circuit. The coupling of the transmitter coil is then increased till the tuning adjustment of one circuit interferes with the tuning adjustment of the other, and the circuits are readjusted, each by its own condenser, for a maximum of current in itelf. The reason for the radical difference in the tuning of the transmitter station in the telephone and telegraph systems may not be obvious. It is due to the fact that in the telegraph it is the actual amplitude of the high-frequency waves propagated along the line that determines the strength or loudness of the signals heard in the receiver, while in the telephone system it is the magnitude of the *variations in amplitude* of the high-frequency waves propagated along the line that determines the loudness of the received speech. Moreover, in the case of the telegraph the loudness of the received signal is the sole object, while in the case of the telephone a still more important requirement is excellence in the quality or articulation of the transmitted speech. In the case of the telegraph, therefore, the adjustment of the transmitter station is such as to produce the maximum amplitude of the transmitted waves, while in the case of the telephone system the adjustment is primarily adapted to securing the best quality of the transmitted speech, and,

[12] J. S. Stone on the "Maximum Current in the Secondary of a Transformer," *Physical Review*, vol. xxxii, No. 4, April, 1911.

P. O. Pedersen, *Uber. d. Empfang kontin. elektromagnet Wellen usw.* in the *Jahrbuch der Drahlosen Telegraphie und Telephonie*, 1910. Also *Resonanz in gekoppelten Schwingungskreisen* in the same journal for 1911.

incidentally, to produce the maximum *variation in amplitude* of the transmitted waves.

Thus, by loosely coupling the primary and secondary circuits at the transmitter and then adjusting the primary circuit for a maximum of current, the reactance of the primary is made zero and the impedance of the primary is reduced to practically the mere resistance of that circuit, so that the resistance of the telephone transmitter becomes practically the sole factor in determining the primary current. Obviously this makes the variations in the amplitude of the high-frequency current due to variations in the resistance of the telephone transmitter a maximum, and, on the other hand, telephone engineers will realize that the elimination, so far as possible, of all reactance and resistance except that of the telephone transmitter, from the primary circuit at the transmitter station, is a prerequisite to good quality or articulation of the transmitted speech.

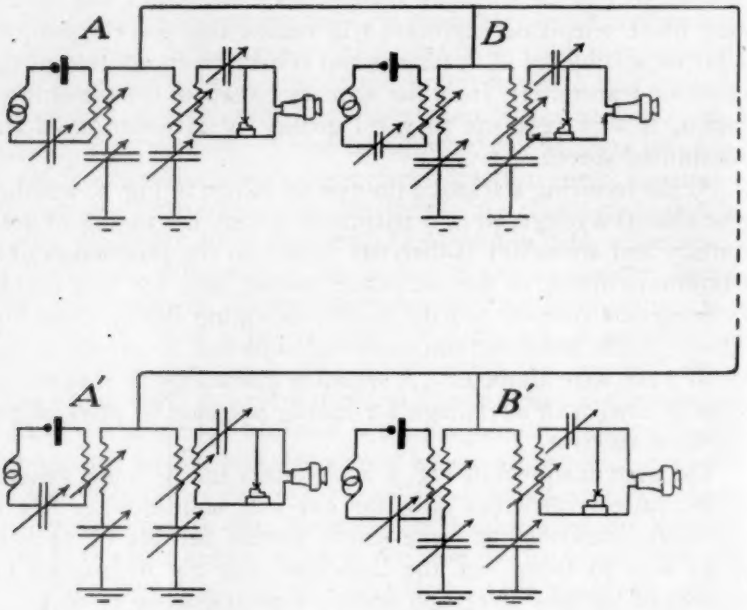
At the receiving station of the system shown in Fig. 1, whether it be used as a telegraph or a telephone system, the tuning of both primary and secondary is directed merely to the production of a maximum current in the secondary circuit, and for this tuning the telephone receiver is used as the indicating device, since the current at the receiving station is not sufficient to permit of the use of a hot wire ammeter. A sensitive galvanometer may sometimes be used with advantage for tuning purposes in place of the telephone receiver.

The system shown in Fig. 1 is obviously not of much general utility, since it provides only for one-way transmission. It is shown and described at some length merely because of its simplicity and to bring out the analogies and the distinguishing features of the new telegraph and the new telephone systems.

A duplex system of high-frequency telephony with two-way transmission for each station is shown in Fig. 2. Again, the simplest practicable arrangement is shown merely for the purposes of illustration, the more complex but more perfect multiplex station being shown in Fig. 3. Each station of the system shown in Fig. 2 combines a transmitter and receiver identical as to apparatus with the transmitter and receiver shown in Fig. 1, and differing from the simplex system of that figure only in the tuning of the stations. In this duplex system the frequency to which a given receiver is adjusted to respond is as remote as

it can conveniently be made from that of the current generated by the transmitter at its own station and from that of the adjacent stations; thus if stations A and A' intercommunicate while stations B and B' intercommunicate, for transmitters of A and B might make use of frequencies of current of, say, 20,000 and 22,000 cycles per second respectively, while the transmitters of stations A' and B' made use of frequencies of 60,000 and 66,000 cycles per second respectively. Of course, then, the receivers of stations A and B would be adjusted to

FIG. 2.

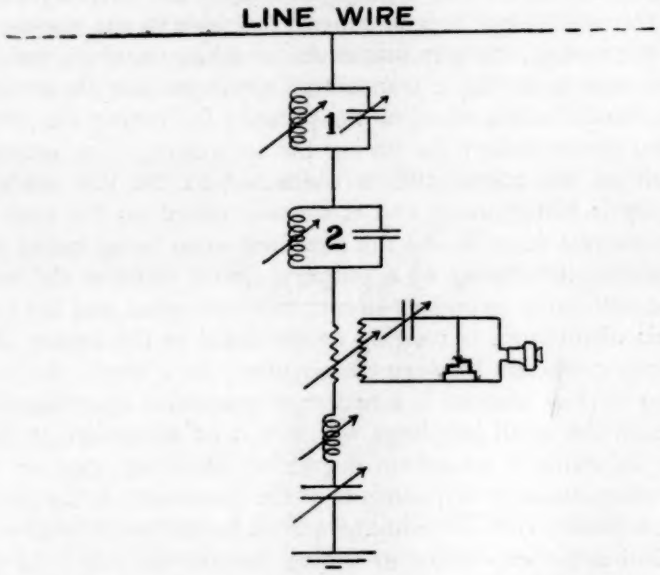


respond to currents of 60,000 and 66,000 cycles respectively, while the receivers of stations A' and B' would be adjusted to respond to currents of 20,000 and 22,000 cycles respectively.

The tuning of the apparatus in the duplex system of Fig. 2, or even of the apparatus of a simplex system with two-way transmission, is not the same as that of the apparatus of the simplex system of Fig. 1, for the reason that in the duplex system and in the two-way transmission simplex system the new element of selectivity is required of the apparatus.

It might not at first seem necessary in a duplex or multiplex system to make the transmitter circuits selective, since the frequency at a transmitter is completely determined by the generator adjustment or the dynamo speed at that station, irrespective of any tuning of its circuits, but on closer examination it will be seen that were a transmitter branch circuit not tuned in such a way as to make it receptive of the current generated at that station and exclusive of currents of other frequencies, currents of all the

FIG. 3.



frequencies used on the line would flow through it, and the variations of resistance of the telephone transmitter or manipulation of the telegraph key in the local circuit at that transmitter station would modify not only the amplitude of the current generated at that station, but would also modify the amplitude of the currents of other frequencies as well, and cause "cross talk" between stations on the line not intended to communicate with each other. Each branch, whether it be a transmitter or a receiver branch circuit, is so tuned that it has *per se*, that is, when disconnected from the line and short-circuited on itself, a minimum of impedance for currents of the frequency it is to select.

The simplest way to accomplish this tuning is to disconnect the branch and local circuit from the line, make the coupling of the coil very small and tune each circuit for a maximum of current by the adjustment of its own condenser. After this preliminary tuning, the coupling may then be increased to any desired extent and the final tuning for maximum current be easily effected. In the case of a receiving station it is in general desirable, in order to secure maximum selectivity, to employ a small coupling, and in tuning the apparatus of a receiving station the electromotive force is impressed upon the primary circuit. In a transmitter coil it is in general desirable to use a somewhat larger coupling, though maximum coupling is never advantageous, and in tuning a transmitter apparatus the electromotive force should be impressed on the primary for tuning the primary and on the secondary for tuning the secondary. The secondary branch of the transmitter is connected to the line while the primary is being tuned, and is short-circuited on the source of electromotive force [13] and the ammeter when being tuned itself. Of course, the tuning of a primary circuit disturbs the tuning of the associated secondary circuit, and *vice versa,* and the extent of this disturbance is roughly proportional to the square of the coupling coefficient between the circuits. As a result, the proper tuning of these stations is a matter of successive approximations, but with the small couplings which it is of advantage to use in order to secure a maximum degree of selectivity, two or three successive, alternate adjustments of the condensers in the primary and secondary circuits only are necessary, particularly after one has had some experience in tuning coupled circuits. As these tunings are of the nature of calibrations and are made once for all for a given frequency, they do not appear to constitute a valid objection to the system on the ground of their complexity or on the ground that they require special skill.

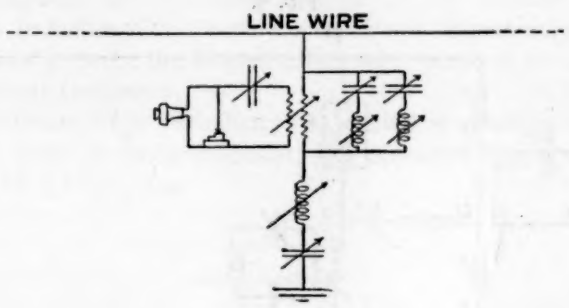
As already stated, the duplex system illustrated in Fig. 2 is a very simple form of the new system, but serves well to illustrate the general characteristics of a high-frequency multiplex system. It lacks, however, a feature the absence of which makes it necessary to choose remotely different frequencies for the use of

[13] The source of electromotive force must, of course, have its reactance neutralized by a separate condenser when it is used to tune a circuit from which it is to be removed after the tuning is completed.

adjacent transmitters and receivers, a fact which would, in many instances, place an arbitrary restriction on the use of wide ranges of frequencies and seriously limit the number of stations which could be simultaneously operated on a single line. The author has devised means which have overcome this difficulty, and three characteristic examples of this means are illustrated in Figs. 3, 4 and 5.

In Fig. 3 the receiver circuit is shown alone, and it is to be noted that in the branch from the line wire there are two loop circuits, 1 and 2, each consisting simply of a condenser and a coil. These loop circuits are each made resonant *per se* to one of two frequencies, currents of which frequencies it is particularly desired to exclude from the receiver. Thus if this receiver were

FIG. 4.



to be used at stations *A* or *B* of Fig. 2, its loop circuits 1 and 2 would be individually made resonant, each to one of the two frequencies generated by the transmitters of stations *A* and *B*, while if it were used at one of the stations *A'* or *B'*, its loop circuits would individually be made resonant each to one of the two frequencies generated at the transmitters of stations *A'* and *B'*. The effect of the presence of one of these looped resonant circuits in the receiver branch is practically to make the branch electrically opaque to currents of the frequency to which the loop is made resonant. So great may be made the impedance of such a loop circuit to high-frequency currents of that particular frequency to which it is attuned that it is possible to operate a system in which the receivers are thus protected against the currents from the transmitters at their own station and at adjacent

stations with less than 10 per cent. difference between the frequencies of the transmitters and receivers. If the apparent resistance presented by a loop circuit be called R' and the apparent reactance of the loop be called K', then

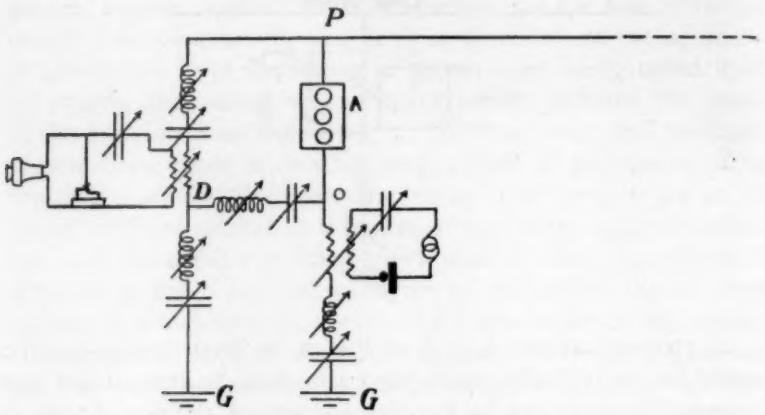
$$R' = \frac{R}{R^2 C^2 \omega^2 + (CL\omega^2 - 1)^2}$$

and

$$K' = -L\omega \frac{R^2 C / L + (CL\omega^2 - 1)}{R^2 C^2 \omega^2 + (CL\omega^2 - 1)^2},$$

where R and L are the resistance and inductance respectively of the coil, C is the capacity of the condenser and ω is the periodicity of the current or 2π times the frequency.

FIG. 5.



When the loop is resonant to the frequency of the current, $CL\omega^2 = 1$, making

$$R' = \frac{L}{CR}$$

and

$$K' = -\frac{1}{C\omega}$$

If in a given case the periodicity be 200,000, corresponding, therefore, to a frequency of 31,850, and if the inductance and resistance of the coil be five millihenrys and one ohm respectively,

then the capacity will be 5×10^{-9} farads. In the case of such a loop, therefore, the apparent resistance of the loop to the currents it is designed to obstruct is one megohm, while the apparent reactance of the loop is one thousand ohms.

The presence of these loop resonant circuits in the receiver branches does not interfere with the tuning of the branches to the frequencies to which the latter are required to respond; in fact, the loop resonant circuits assist in such tuning, since for frequencies of currents higher than that, the passage of which a given loop circuit is adjusted to obstruct, the loop circuit presents an apparent capacity reactance and but small apparent resistance, while for frequencies of current lower than that, the passage of which it is adjusted to obstruct, the loop presents an apparent inductance reactance with but small apparent resistance. These apparent capacity and inductance reactances are balanced by the adjustable inductance and capacity reactance respectively of the branch so as to make the branch selectively receptive of currents of the desired frequency.

For currents of a periodicity ω_1 which is n times that to which the loop is made resonant, the apparent resistance and reactance of the loop are:

$$R' = \frac{R}{n^2R^2\frac{C}{L} + (n^2-1)^2}$$

and

$$K' = -nL_\omega \frac{R^2\frac{C}{L} + n^2 - 1}{n^2R^2\frac{C}{L} + (n^2-1)^2}$$

In the case of the particular loop circuit just considered

$$R' = R/\left\{10^{-6}n^2 + (n^2-1)^2\right\}$$

and

$$K' = -10^3 n \frac{10^{-6} + n^2 - 1}{10^{-6}n^2 + (n^2-1)^2}$$

If, therefore, in the case of the loop circuit in question, the branch containing it is made responsive to currents of a frequency 10 per cent. different from that of the current which the loop is adjusted to exclude, n is 1.1 or 0.9 and the apparent resistance of

the loop to currents of this frequency is 22.7 or 27.7 ohms, depending on whether the frequency of the current to be excluded is lower or higher, respectively, than the frequency of that to which the branch is attuned to respond.

If the current to be excluded is of the higher frequency, then the apparent reactance of the loop in the branch is an inductance reactance of 4740 ohms, while if it be the lower frequency, the apparent reactance of the loop is a capacity reactance of 5240 ohms. In place of the loop circuits shown in Fig. 3, loop circuits inductively coupled with the receiver branch may be used.

The author has discussed in a more comprehensive manner the tuning of conductors containing looped circuits so as to exclude currents of one particular frequency while making the conductor selectively responsive to currents of another particular frequency in a paper read before the Electrical Section of the Canadian Society of Civil Engineers, March 9, 1905.[14]

The arrangement of receiving apparatus shown in Fig. 4 shunts the currents from the neighboring transmitters out of the receiver by means of branch circuits separately made resonant, one to each of the frequencies generated at adjacent or nearby stations.[15]

The arrangement of Fig. 5 is typical of the induction balance circuit which can be used to render a receiver irresponsive to the currents generated by the transmitter at the same station. In this arrangement, the branch *G O* is separately tuned to the transmitter frequency, while the branches *O D*, *P D* and *D G* are separately tuned to the receiver's frequency. The device *A* is one having adjustable resistance, inductance, and capacity, and whose vector impedance may be made to correspond to any scalar multiple of the vector impedance of the line measured from the point P outward.

The transmitter and receiver branches *O G* and *P D* respectively are conjugate, the vector product of the vector impedance of the branches *O P* and *D G* being equal to the vector product of the vector impedance of the branch *O D* and that of the line. Bridges of this kind must be balanced both for the resistances and for the reactances of the branches.[16]

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[14] See also U. S. Patents to Stone, Nos. 767,994 and 767,995.

[15] See U. S. Patents to Stone, Nos. 884,106, 884,107, 884,108, and 884,109.

[16] See "Electrical Papers" of Oliver Heaviside, vol. ii, pp. 33–38 and 366.

It is evident that when the conditions tending to produce interference in a receiver by a neighboring transmitter are exceptionally severe, the methods of freeing the receiver from such interference shown in Figs. 3 and 4 may be combined in the receiver without any difficulty. With a receiver so protected against "cross talk," the amount of energy of the current to be excluded may be millions of times greater than that of the current to be received and differ from the latter in frequency by but a few per cent. without causing the least interference.

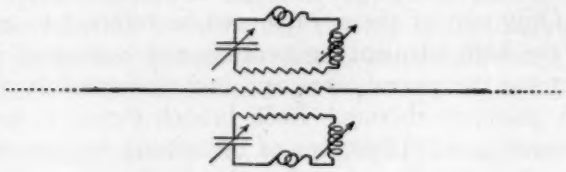
A most important feature of both existing telegraphy and telephony is the centralization of the current supply, and this feature is, fortunately, most easily realized in the new high-frequency telegraphy and telephony. It brings the high-frequency generators, whether they be high-frequency dynamos or oscillators, under the constant supervision and care of a trained man at the central office. The author has devised several ways in which the centralization of the energy may be practically accomplished. Only two of these ways need be referred to here. In the first, the high-frequency generators are connected in series in the circuit at the central office, and each is shunted by a number of branch resonant circuits. Each branch circuit is separately made resonant to a different one of the several frequencies of the currents used on the line other than that of the current developed by the generator it shunts. Another practical mode of centralizing the energy is shown in Fig. 6. The several generators, each in a local circuit tuned to its own frequency, are brought into inductive relation with a transformer secondary in series or in parallel with the telephone or telegraph circuit. The generators in the centralized energy system develop higher potentials than those designed to be used at sub-stations, or else the voltage of the generator is stepped up to the desired voltage.

An allied arrangement, first suggested by Dr. Louis Duncan, contemplates using the high-frequency current only on trunk circuits. In this arrangement, which there is not space here to discuss in detail, a telegraph or telephone relay at the central office translates the telegraph or telephone message bearing current from the existing sub-station line equipped with its local or centralized battery supply into a high-frequency telegraph or telephone current on the trunk circuit, and conversely the high-frequency telegraph or telephone current on the trunk circuit

is translated from that circuit to the local or sub-station battery circuit by a telegraph or telephone relay or by a rectifier. It is of interest to note that the most serious objections to the telephone relays lose their force in this application, because the telephone relay so used need not amplify the telephonic transmission, and it is in its function as an amplifier that the telephone relay has met conditions which have brought it into disrepute.

In this paper no more than a passing reference has been made to the extremely important fact that multiplex high-frequency telegraph and telephone systems may be superposed on existing telegraph and telephone circuits without bringing about the least mutual interference between the old and the new systems, and this subject and its important practical aspects will not be further dwelt upon here because it has received a fairly complete exposition at the hands of Major George O. Squier, both in his

FIG. 6.



patents and in his paper before the American Institute of Electrical Engineers, to which references have been made. Only such features of high-frequency telegraphy and telephony as have not elsewhere been adequately brought out or discussed so as to make clear their bearing upon the future practical application of the propagation of high-frequency currents or electric waves along wires will be dwelt upon. This course, though it imparts to the paper a fragmentary character and an appearance of incompleteness, serves to keep it within reasonable bounds and should not diminish its utility, in view of the references given to other publications.

There is an element of every system of transmitting intelligence, namely, the *call* and its allied automatic circuit control mechanisms, which has been highly elaborated, particularly in the older system of telephony. In the new high-frequency telegraphy or telephony, when used by itself, either as a simplex or multiplex, the *call* and automatic circuit control mechanism system

generally need not be different from that in use to-day in the older systems, but in lieu of this the call may be effected by a very flexible system of selective low-frequency electric signalling over the same line. In this selective signalling system, each of a number of stations on the same line is called by the use of a low-frequency alternating current of a different frequency thrown on the line, and the selection of the signalling current at the different stations called is effected by electrically resonant local circuits or branches at these stations, each attuned to the frequency of the particular alternating signalling current by which it is intended to be operated.[17]

The description of this system of selective signalling needs little amplification here, since it has long been known and is discussed in detail in the reference given, as well as in numerous patents to Professor Pupin, Messrs. Hutin & Leblanc, and to the author. There is just one new feature in the system, however, which should be mentioned, namely, that by the addition of rectifiers in the local branch signal receiving circuits the author believes that he has overcome the principal hindrance to the practical application of the system in the past. By this simple device the *call* at each station may be sounded by a vibrator bell of a uniform pattern. There seems little doubt that this extremely simple and flexible selective signalling system would long since have become popular for *party line selective calling* in the existing telephone system except for the fact that it demanded the use of some special, unsatisfactory, and unusual call device, different at each station.

When the high-frequency system is used in conjunction with, and on the same line as, the existing system of telegraphy and telephony, a separate high-frequency call or signalling system is preferably used. This call or signalling system is identical with the high-frequency telegraph system itself, except that it operates a local battery call device, such as a vibrator bell or buzzer, instead of operating a telephone receiver, and for this reason it is necessary that the calling current manifest more energy at a distant station than does the corresponding high-frequency telegraph or telephone current under similar conditions. To

[17] See record for Stone, Pupin, and Hutin & Leblanc in interference in the U. S. Patent Office No. 17,196.

accomplish this purpose a relay of great sensibility and extreme sluggishness of action is used in conjunction with a rectifier in a tuned local circuit at the receiver station. To call the station, a high-frequency current of the same frequency as that to which the local circuit at the receiver containing the rectifier and relay is attuned is thrown upon the line and maintained thereon until the sluggish relay has time to respond and close the local battery circuit containing the vibrator bell or buzzer.

The relay which the author has found to best meet this requirement of great sensibility through sluggishness of action, is of the Weston moving coil type. It has very high resistance and has an electro-magnet producing an extremely intense field in place of the permanent magnet of the usual Weston instrument. This method of effecting a call, which involves the integrating of the energy of the received current over a relatively long period of time by the use of a receiving device, extremely sluggish in its response, is imported from radio-telegraphy, where it was first used by the German company, the Gesellschaft für Drahtlose Telegraphie of Berlin. Experiments have not yet, so far as the author is aware, shown whether it is possible to operate this selective call over as great a length of line as it is possible to telephone or to telegraph at ordinary speed with a current of the same frequency, but the promise is good.

A great advantage enjoyed by the new high-frequency telephone system over the existing system is in the important particular of *distortion*. In the existing system of telephony, the currents as they are propagated along the line suffer a continual *attenuation* or a loss of amplitude, an effect to be minimized as far as possible. Still more harmful, however, in general, is the distortion of the telephone current which it engenders through the fact that the component alternating currents of different frequencies which make up the telephone current are unequally attenuated. Usually, therefore, long before a telephone current has been attenuated to a point at which it is too feeble to be of use, it has been so far distorted as to be incapable of producing intelligible speech at the receiver. In other words, considerably more attenuation than is now tolerable could be permitted in telephone systems were it not for the distortion that usually accompanies it.

In the new high-frequency system of telephony, *attenuation, though greater than in the older system, brings with it no distor-*

tion whatever. There is, in fact, in the transmission of a given message, but a single frequency of current involved, and therefore no unequal attenuation of components of different frequencies and no distortion.

Another signal advantage of the new high-frequency telephone system over the existing system lies in the *silent line*[18] which it enjoys. Were it not for the noisiness of the average telephone line in the existing system, telephone receivers of far greater sensibility could be used with advantage, and, furthermore, a much fainter transmitted speech would be easily understood and even prove more acceptable to the telephone subscriber than the louder transmission does on the average telephone line to-day. In the new telephone system, telephone receivers of several thousand ohms are used, having correspondingly greater sensibility than the low-resistance receivers in use in the existing telephone system.[19] Moreover, transmitted speech which is so faint that it would be completely swamped and ineffective on even a moderately noisy line is heard and understood against a background, as it were, of absolute silence.

The absence of distortion and the silent line of the new telephony remove the chief obstacle to the use of the telephonic amplifier at or near the receiving end of a long line to compensate for the weakening effects of attenuation on the current. In this connection it is to be noted that in the existing system, when a telephone current has been sufficiently attenuated in passing over a long line to require amplification, it is also so distorted, and so intermixed and confused with *line noise currents* which the amplifier would bring out or intensify that a telephone relay for

[18] The receivers in the new system are not only unaffected by the usual *cross talk* or induction between adjacent telephone circuits, and by inductive disturbances generally, that so often cause confusing noises in the receivers of the existing telephone system, but they are, moreover, mute to their own transmitters. In other words, there is in the new system no so-called *side tone*, and the user of the system speaks as loudly as he pleases into his transmitter without deafening himself by hearing the sound of his own voice rasping in his own telephone receiver, as so often happens in the existing system.

[19] The sensitiveness of a telephone receiver is approximately proportional to the square root of the resistance of its windings. In connection with the centralized energy systems in the United States, telephone receivers of from 20 to 60 ohms are used. The telephone receivers employed in the new high-frequency system are of 2,000 ohms resistance.

amplification purposes, no matter how perfect it might be in itself, has by some engineers long been regarded as of little value. Another influence which has militated against the utility of amplifiers in telephony in the past is that for two-way transmission the amplifier has a persistent tendency to sing to itself in much the same manner and for much the same reason that a telephone receiver sings to its transmitter when it is held in front of the mouthpiece of the latter if the efficiency of the combination is sufficiently great. The greater the amplifying power of the telephone relay, the more persistent this tendency to sing to itself, and to overcome it resort has been had to so-called *telephone relay circuits*, which seek to exclude the current developed by the transmitter element of the amplifier from its receiver element. These *telephone relay circuits* are essentially induction balances in which the transmitter and receiver elements of the amplifier are in conjugate branches and the line wire forms one or more arms of the balance. In the case of an amplifier that really amplifies, the least change in the line conditions upsets the balance sufficiently to set the amplifier singing to itself and, even in the case of constant attention on the part of a skilled operator, this, at least temporarily, causes an interruption of service. In high-frequency telephony no such restraining conditions operate against the use of amplifiers for two-way transmission, since the current from the transmitter element and that directed to the receiver element are of different frequencies and the receiver element is placed in a branch or local circuit adjusted to exclude the current from the transmitter element, irrespective of the conditions of the line.

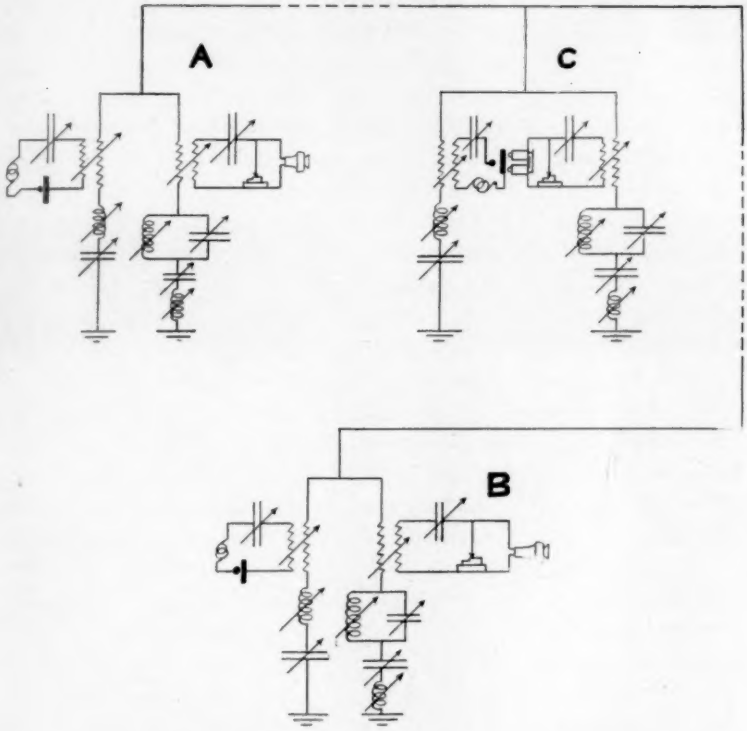
Fig. 7 shows a typical arrangement of a telephone amplifier adapted for two-way transmission in a system of high-frequency telephony.[20] In it the transmitters and receivers are the same as those already shown and described, and at the amplifier station *C*, the transmitter and receiver elements are the same as the transmitters and receivers shown at *A* and *B*. In such a system the transmitters at both stations *A* and *B* develop currents of the same frequency, this frequency being that of the current to which the receiver element of the amplifier is responsive, while the receivers at both stations *A* and *B* are selective of currents of another fre-

[20] See U. S. Patents to J. S. Stone, Nos. 717,515 and 717,467, both of Dec. 30, 1902.

quency, this second frequency being that of the current developed by the transmitter element of the amplifier.

It is not the intention here to imply that the existing telephone amplifiers are all that could be desired, but the author believes that he is not alone among telephone engineers in holding the view that the disrepute into which these instruments have fallen is due in a

FIG. 7.



very large measure to the disabilities which they suffer when an attempt is made to fit them into the existing system of telephony, a system to which, as has here been shown, the telephone amplifier is ill adapted.[21]

[21] A new telephone relay amplifier has recently been discovered which is entirely electrical in its action, having no moving parts whatever. It is productive of great amplification, and it appears to do this without appreciably distorting the telephone current.

The most serious obstacle to the successful use of the new high-frequency telegraph and telephone is undoubtedly the excessive attenuation or progressive weakening of its current as it flows along the line, particularly in cable circuits, and unless countervailing or remedial conditions can be found, the use of these high-frequency systems must be very materially restricted through being confined to relatively short lines.

The average frequency of the ordinary telephone current is about 800 cycles per second, but the highest harmonics range between 4,000 and 5,000 cycles, and it has been found that it is necessary, for the complete clearness of articulation of the transmitted speech, to conserve harmonics up to about 1,500 cycles.[22] The highest useful frequency in ordinary telephony is, therefore, about one-tenth of the lowest frequency which Major Squier's experiments seem to indicate as possibly practicable for the new telephony, and about one-seventieth of the highest frequency regarded as practicable by Major Squier for the new system. In making comparisons of the attenuation in the old and new systems these ratios should be borne in mind.

Since in the new system of telephony a greater current is thrown on the line than in the existing system, and since, further, a receiver of very much greater sensibility is employed, evidently a considerably greater attenuation of the current of the system is permissible than could be tolerated in the old system, and when, further, the absence of noise, the absence of *distortion*, the absence of *side tone*, and the absence of reflection of energy from the receiving end of the line are taken into consideration, it seems conservative to estimate that the maximum practical permissible *attenuation length* in the new telephony is 6.9, as compared with 4.6 in the existing system. An example of how this affects the range of transmission of the new system may perhaps be best gathered from a concrete example, and for this purpose an open-wire telephone line construction will be chosen which is of a type in most common use in the United States for transmission to distances up to 450 miles. This line is of the two-wire or so-called *metallic circuit* type, in which the wires are of hard-drawn copper 0.104 inch in diameter, and are separated on the cross-arms by

[22] See B. S. Cohen, *Phil. Mag.*, Sept., 1908; also *Proc. Phys. Soc. London*, vol. xxi.

a distance of 12 inches. Assuming for this line an insulation resistance of one megohm per mile, the ratio of the attenuation constant for currents of 1,500 and 100,000 cycles per second respectively is very closely 3, and, other things being equal, this would mean that the new system could not be used to transmit speech over more than 150 miles of such a circuit. On the basis of an attenuation length of 6.9, however, it would seem that practical transmission of speech by the new system could be had over a length of 225 miles of this circuit. The disparity between the distances to which unaided transmission may be had by the existing and the new system is somewhat greater in the case of open-wire circuits of larger than of smaller wire, and this disparity is, in general, greater in the case of cable circuits than in the case of open-wire circuits.

Even if no effective means be found to extend the range of the new high-frequency telephony, few will seriously contend that there is no practical gain to be realized in making use of a 450-mile circuit as it is at present used and further simultaneously employing it in two sections, each 225 miles in length, for the multiple transmission of, say, forty-two messages, twenty-one on each section.[23]

Before leaving the subject of the attenuation of high-frequency waves propagated along conductors, it is worth while to note that the expressions for the attenuation constant and the wave length or wave speed on copper open-wire circuits is much simpler than it is in the case of waves of lower frequencies, and the reader will find that he may easily compute the attenuation and wave length or wave speed in the case of any given circuit.

The complete expression for the attenuation constant per centimetre of a uniform unloaded circuit is

$$\alpha = \left[\tfrac{1}{2} \left\{ (R^2 + L^2\omega^2)^{\frac{1}{2}} (S^2 + C^2\omega^2)^{\frac{1}{2}} + (RS - CL\omega^2) \right\} \right]^{\frac{1}{2}}$$

in which expression R, L, C, and S are the resistance, inductance, capacity, and leakage conductance respectively, all in absolute elec-

[23] The number of stations which can be used in any given case is the nearest whole number to

$$1 + \frac{0.82393}{\log_{10}(1 + \Delta)}$$

where 100Δ is the least percentage difference permissible between frequencies. The number of stations assumed in the above example is on the basis of a 10 per cent. difference between the frequencies.

tromagnetic units per centimetre, and ω is the periodicity or $2n$ times the frequency of the waves.

Making use of the relation

$$CL = \frac{1}{v^2} + \vartheta C,$$

in which v is 3×10^{10}, writing a for $\frac{R}{L\omega}$ and b for $\frac{S}{C\omega}$, the expression for α becomes

$$\alpha = \left[\frac{(1 + \vartheta C v^2)\omega^2}{2v^2}\left\{(1 + a^2 + b^2 + a^2b^2)\right\}\right]^{\frac{1}{2}}$$

But $a^2\ b^2$ is negligible compared to unity, $a^2 + b^2$ is small compared to unity, and so also is $\vartheta\ C\ v^2$. Consequently, by the use of the approximation

$$(1 + \delta)^{\frac{1}{2}} = 1 + \frac{\delta}{2}, \text{ where } \delta \text{ is small compared to unity,}$$

the expression for α reduces to

$$\alpha = \frac{\omega}{2v}\left(1 + \vartheta\frac{Cv^2}{2}\right)\left(a + b\right)$$

The complete expression for the wave length in centimetres is

$$\lambda = \frac{2\pi}{\beta}$$

where

$$\beta = \left[\frac{1}{2}\left\{(R^2 + L^2\omega^2)^{\frac{1}{2}}(S^2 + C^2\omega^2)^{\frac{1}{2}} - (RS - CL\omega^2)\right\}\right]^{\frac{1}{2}}$$

For high frequencies this reduces to

$$\beta = \frac{\omega}{v}\left(1 + \vartheta\frac{Cv^2}{2}\right)^{\frac{1}{2}}\left\{1 + \frac{1}{8}\left(a - b\right)\right\}$$

The velocity of propagation of the waves is $V = \frac{\omega}{\beta}$ in centimetres per second.

To express the attenuation constant a and the wave length constant β in terms of miles instead of centimetres they may be multiplied by 160,934.4, the number of centimetres in a mile.

In the above expressions

$$C = \frac{1}{4v^2 \log_e \frac{d}{r}}$$

where d is the distance between the two wires of the circuit in any units and r is the radius of the wire in the same units.

$$L = \frac{1}{Cv^2} + \vartheta$$

$$R = R_{\omega=0}\left(1 + \frac{k^2}{48} - \frac{k^4}{2880} \cdots\cdots\right.$$

where $R_{\omega=0}$ is the resistance of the wire to low-frequency or direct currents and

$$k = \frac{nc^2}{\rho}$$

where n is the frequency of the waves, c is the circumference of the wire, and ρ is the resistivity of the material of the wire in absolute electromagnetic units per centimetre.[3] For hard drawn copper at 75° F., ρ may be taken as 1748.

When k is large, say at least equal to 6, then the simpler expression

$$R = R_{\omega=0}\left(\frac{1}{2}\sqrt{k}\right)$$

may be used.

When k is less than 8,

$$\vartheta = 1 - \frac{k^2}{96} + \frac{13k^4}{69120} \cdots\cdots$$

and when k is greater than 8,

$$\vartheta = \frac{2}{\sqrt{k}}$$

One megohm per mile makes $S = 6.214 \times 10^{-21}$ absolute electromagnetic units per centimetre.[3]

Except for the development of these new simplified expressions for α and β, the mathematical theory of the subject of electric wave propagation on conductors has been so exhaustively treated elsewhere as to need no restatement here.

The reader who wishes to pursue this mathematical theory for the sake of its intrinsic beauty and interest can do no better than to consult the works of the great master of the subject, Mr. Oliver Heaviside, whose collected papers are entitled "Electrical Papers" and "Electromagnetic Theory." He will find these works to be a rich mine of information on the subject, and he will also find that the similarity of these books to a mine extends to the method by which he will have to extract his information from them. A much simpler and more concise though more restricted and utilitarian discussion of the subject is to be found in Prof. J. A. Fleming's book, entitled "The Propagation of Electric Currents in Telephone and Telegraph Conductors," which brings out, perhaps more clearly than any other of his numerous writings, Professor Fleming's unusual powers of simple and clear exposition of technical subjects of exceptional complexity—a quality the more to be admired because of its rarity in English technical and scientific writings.

In the existing system of telephony, when it is necessary to diminish the attenuation on a line without increasing the size of the wire used or the separation between the wires, resort is had to methods of diminishing the attenuation constant by diminishing the quantity a, this being done by adding inductance to the line without producing a proportionate increase in its resistance. A circuit so treated is said to be "loaded" with inductance and is called a "loaded" circuit. Two methods have been used. In one the added inductance is uniformly distributed along the line and is secured by wrapping the insulated wire with a winding of iron wire. This method of loading cables has found favor in Germany and Holland.[24] In England, France, and the United States the only method of loading telephone lines used is by means of a system variously ascribed to M. I Pupin,[25] to G. A. Camp-

[24] "Moderne Telefonkabler," by Mr. C. E. Krarup, Elektroteknikeren, Dec. 10, 1904.

"On Submarine Cables for Long-distance Telephone Circuits," by Major O'Meara, *Jour. Inst. Elect. Eng.*, London, Nov., 1910.

U. S. Patent to J. S. Stone, No. 578,275, of March 2, 1897.

[25] "Propagation of Long Electrical Waves," by M. I. Pupin, Trans. A.I.E.E., March, 1899.

"Wave Transmission over Non-uniform Cables and Long-distance Air Lines," by M. I. Pupin, Trans. A.I.E.E., May, 1900.

bell,[26] to Sylvanus P. Thompson,[27] and last, but by no means least, to A. Vaschy.[28] In this *multi-patratus* system of loading lines inductance coils having time constants $\frac{L_1}{R_1}$ larger than the time constant per unit length of the unloaded line $\frac{L}{R}$ are introduced in the circuit at equal intervals, small compared to one-half the wave length of the highest frequency component of the telephone current to be conserved in transmission.

The method of loading lines by uniformly distributed added ferric inductance would seem, on its face, to be available for the high-frequency systems of telegraphy and telephony, but it suffers from several disadvantages. In the first place, it is ill adapted for open-wire circuits; in the second place, it renders cables excessively heavy and bulky; in the third place, it is impossible to predetermine the attenuation constant of such a circuit, and, in the fourth place, there is evidence tending to show that when a cable so loaded is used in connection with high-frequency currents the dissipation of energy due to hysteresis in the iron wrapping will largely, if not wholly, compensate the beneficial effects of the increased inductance of the circuit.[29]

The use of the second system of loading lines would seem to be precluded by the expense involved. The number of loading

[26] Records for Pupin & Campbell in interference in the U. S. Patent Office No. 20,699, also *Phil. Mag.*, vol. v, p. 319, March, 1903.

[27] "Ocean Telephony," by S. P. Thompson, *Trans. Int. Elect. Congress*, 1893; also English Patents Nos. 13,064 and 15,217 of 1893.

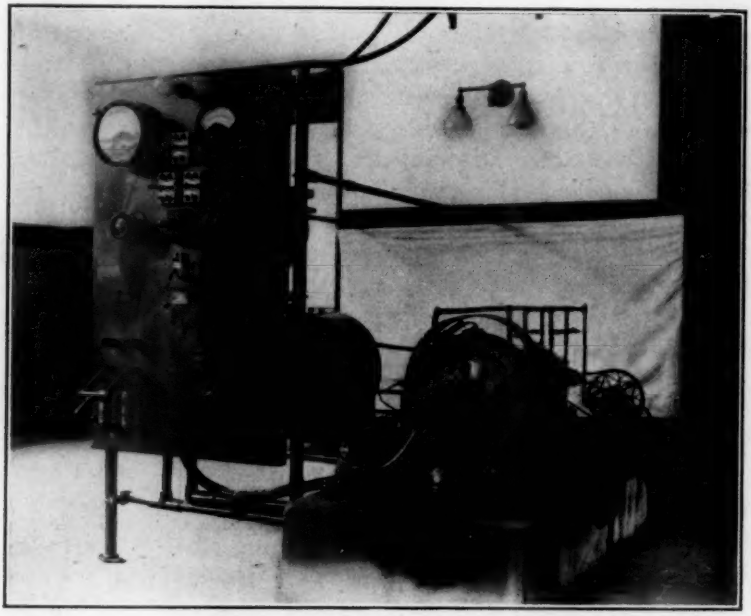
[28] A. Vaschy's numerous mathematical discussions bearing upon this subject are to be found in *Annales Telegraphique* 1888, '89, in his *Électricité et Magnétisme*, and in *L'Éclairage Électrique* 1897, and elsewhere.

[29] The effect of dissipation of energy in the iron wire wrapping is to increase the effective or apparent resistance of the copper conductor. Thus in the Seeland-Samso-Jutland cable, which is about 20 nautical miles in length and is uniformly loaded by iron wire wrapping, the inductance is increased 868 per cent., and the apparent resistance to a current of 900 frequency is 5 per cent. greater than to a direct current. What proportion of this increase in the effective resistance of the copper conductor is due to hysteresis loss in the iron wrapping is as yet undetermined. If it were wholly due to hysteresis, then it would be approximately 550 per cent. at 100,000 frequency, but probably not more than one-half of the increase in effective resistance of the copper conductor is due to this cause. The remainder is due to the unequal distribution or the imperfect penetration of the alternating current into the copper wire.

coils used would have to be about 70 times as great for the 100,000 frequency current of the new system as is now used on the basis of approximately 4.5 coils per wave length for a current of 1,500 frequency.

Since, for equal degree of loading of the line in the new and the old systems, the inductance of the coils used for currents of 100,000 frequency would be but one-seventieth of that of the coils used in the old system, it might at first glance seem as if the coils

FIG. 8.

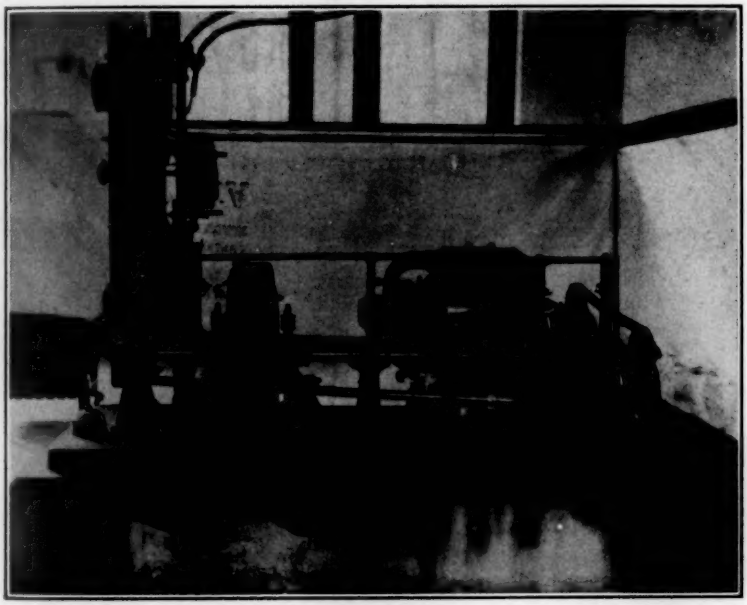


Alexandarson high-frequency dynamo and switchboard.

would be correspondingly cheaper, and that, consequently, the disparity in the cost of loading the line in the two systems would result chiefly from the greater cost of labor in installing the more numerous coils in the case of the new system. But this conclusion is not justified, because the time constant of the coils in the case of the new system must be as great as in the older system, and the bulk, weight, and cost of coils depend far more on their time constants than on their inductances.

So far from these systems of loading lines with inductance holding out hope of improving the range of high-frequency telegraphy and telephony, the very fact that many trunk circuits are already loaded with coils for the improvement of the existing system bids fair to interfere with the extension of the high-frequency system to these lines. To apply the high-frequency system to a line which is loaded for the existing system it becomes necessary to shunt the loading coils by condensers which shall act practically

FIG. 9.



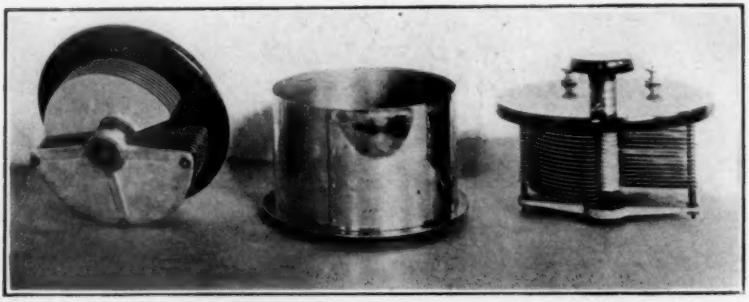
The Alexandarson high-frequency two-kilowatt dynamo, showing the driving electric motor and Delaval gear.

as a short circuit to the loading coils for the high-frequency currents and which shall act practically as an inappreciable shunt to them for the low-frequency telephone current. The cost and inconvenience of this would probably not offset the advantages to be gained from the increased effective number of circuits secured, but, however this may be, it is a fact that, so far as can be seen at present, *the high-frequency system will not be applied to more*

than one circuit on a pole line or in a cable, and this one circuit could be left unloaded without great loss.

The reason that but one circuit on a pole line or in a cable, as these are at present constructed, can with advantage be multipled by the new high-frequency system is that the transposition of the wires on the existing pole lines and the twisting of the pairs of wires in the existing cables are adapted to give workable freedom from cross talk between the circuits with the existing frequency of current, the existing strength of current at the transmitter, and the existing sensitiveness of the receiver. When all these quantities are augmented, as they are in the high-frequency system, energy will flow from one circuit to another in the same cable or on the same pole line to an extent that will preclude the use of the same frequency of current for the transmission of different messages on different circuits in the same cable or on the same pole line.

FIG. 10.



Type of adjustable condenser used in the new system.

In the latter half of this paper the new system has been treated more particularly in reference to its application to trunk lines, but the promise it holds out of a twenty-party sub-station telephone line with not only selective calling but selective or multiple speech transmission may to some, in itself, seem sufficient to justify the money that has been expended and the patient, unrequited human effort that has been freely given in bringing the new system to its present state of development, and to warrant the further effort and expenditures which will be necessary before it can yield its full service to society.

AN OUTLINE OF THE THEORY OF BALLOONING.[1]

BY

MAJOR SAMUEL REBER,

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IN the endeavor to condense the outline of the theory of ballooning into the compass of one lecture, the writer has perforce been compelled to omit a number of interesting propositions and to state the principles involved in the briefest possible manner. He hopes, however, the following may lead to a further study of this most interesting subject and that the principles set forth will assist the class in understanding the reasons for the various operations involved in the manœuvring of a balloon.

In this discussion the constants of the international standard atmosphere as expressed in English units have been employed. The international standard atmosphere is the atmosphere which, at sea level, in latitude 45, at a temperature of 32° F., gives a pressure of 2,111 pounds per square foot (14.66 pounds per square inch or 29.921 inches of mercury) where no vapor of water is present. Under these conditions a cubic foot of air weighs 0.080529 pound. The following notation has been adopted and the subscript zero is employed to indicate that the value of the quantity to which it is attached is taken at sea level or at the starting point of the balloon:

V, the volume of the balloon in cubic feet.

z, the height of balloon in feet above sea level, or starting point.

a, the weight of a cubic foot of air.

b, the weight of a cubic foot of the gas filling the balloon.

d, the density of the gas in terms of air as unity.

p, the pressure of air or gas.

v, the volume of air or gas.

f_0, the ascensional force of the gas in pounds.

f, the starting ballast in pounds.

F, the total ascensional force of the gas filling the balloon, in pounds.

Φ, the ascensional force of the balloon, in pounds.

w, the solid weight of the balloon, in pounds.

[1] Lecture delivered at the Army Signal Station, Fort Omaha, May 27, 1912.

From the standpoint of the balloonist the atmosphere is a perfect mixture of oxygen and nitrogen in the proportion of one to four, with a trace of carbonic acid gas and a varying amount of vapor of water. It behaves as a perfect gas and obeys the laws of Mariotte and Charles as expressed by the formula

$$pv = 57T \qquad (1)$$

in which T is the absolute temperature of the atmosphere on the Fahrenheit scale and 57 is the gas constant for the standard atmosphere.

The pressure and volume of the atmosphere at any temperature t can be expressed in terms of a standard pressure p_0 and volume v_0 at 32° F., as follows:

$$pv = p_0 v_0 (1 - 0.002039 [t - 32°]) \qquad (2)$$

The weight of a cubic foot of air varies with the geographical position of the place, with its elevation above the sea level, with the temperature and pressure, and with the amount of vapor of water in the air. The variation in the weight due to the latitude and elevation above sea level is given by the following:

$$a = a_0 (1 - 0.0026 \cos 2\phi - 0.0000003z) \qquad (3)$$

in which ϕ is the latitude and z the elevation in feet above sea level. For any heights that a balloon can reach, the altitude term can be considered as negligible. This is also true of the latitude term, as in passing from latitude 45 to the poles or the equator the weight of a cubic foot of air is increased or diminished only by 26 parts in 10,000.

If the temperature remain constant the law of Mariotte applies and the weight of a cubic foot of air, due to the variations in the pressure of the atmosphere, is expressed as follows:

$$a = \frac{p}{2111} a_0 = \frac{h}{29.921} a_0 \qquad (4)$$

h being the corrected height of the mercury column or the reading of the aneroid. The change in weight due to extreme variations in barometric pressure can hardly exceed 5 per cent. of the standard value.

If the pressure remain the same the change in weight due to difference in temperature is given by Charles's law as follows:

$$a = a_0 (1 - 0.002039 [t - 32°]) \qquad (5)$$

in which t is the temperature of the atmosphere expressed in degrees Fahrenheit. The variation in weight due to extreme temperature variations in the vicinity of Fort Leavenworth and Fort Omaha can amount to as much as 20 per cent.

Due to the pressure of vapor of water in the air, the true pressure of the air is the difference between the total pressure and the tension of the vapor of water present. If e is the tension of the vapor of water, the weight of the unit volume of air is

$$a = a_0 \frac{p - e}{2111}$$

The weight of the vapor of water is $\frac{a_0 de}{2111}$ and the combined weight of the air and the vapor of water is

$$a = \frac{a_0}{2111} (p - e [1 - d]).$$

Taking the density of the vapor of water as 0.622, the above reduces to the following:

$$a = \frac{a_0 (p - 0.378e)}{2111} \qquad (6)$$

The weight of a cubic foot of air, taking into consideration the effect of variation of atmospheric pressure and temperature and the amount of vapor of water present, is as follows:

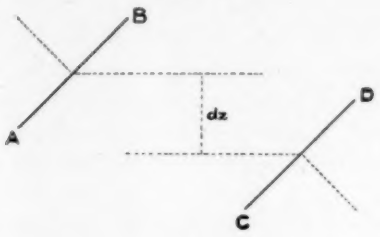
$$a = 0.08 \frac{(p - 0.378e)}{2111} (1 - .002[t - 32°]) \qquad (7)$$

At Fort Omaha, where the mean height of the barometer is 28.837, the mean temperature 50° F., and the mean vapor tension 0.3 inch of mercury, the mean weight of a cubic foot of air is 0.07457 pound.

For any two small surfaces *AB CD* (Fig. 1), immersed in a gaseous mass in equilibrium and subjected to the force of gravity alone, Pascal's principle states that each surface will be acted upon at its centre of gravity by a pressure which is normal to it and independent of its direction, and that the difference of pressure between the two surfaces is equal to the weight of a unit volume of gas multiplied by the vertical distance

between the centres of gravity of the surfaces. If dp represent the difference in pressure between these surfaces and dz the

FIG. 1.



vertical distance between their centres of gravity, we have from the above principle:

$$dp = adz. \tag{8}$$

This principle can be applied at once to determine the law governing the variation of atmospheric pressure with height under the assumption that the weight of a unit volume of air at any altitude is proportional to the pressure at that altitude, or

$$\frac{p_o}{a_o} = \frac{p}{a} = A \tag{9}$$

this assumption implying that the ratio is independent of the height. Taking the values for the standard atmosphere, we have as a value for the constant

$$A = \frac{2111}{.080529} = 26217,$$

or, in other words, if the density of the air is uniform throughout the column, the height of a homogeneous atmosphere would be 26,217 feet.

In Fig. 2, let $H_o\ H_o$ represent sea level, $H\ H$ a plane z feet above it, here the pressure is p, and $H'\ H'$ another horizontal plane above and infinitely near the plane $H\ H$. The difference in pressure between these two planes is

$$dp = -adz \tag{10}$$

the minus sign indicating that the pressure is acting downward. Using the values in equation 9, we have

$$dz = -A\frac{dp}{p} \tag{11}$$

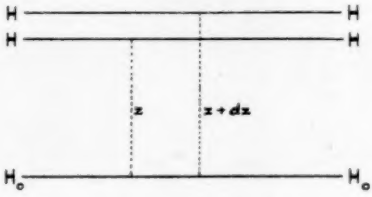
$$dz = -A\frac{da}{a} \tag{12}$$

Integrating, we have

$$z = -A\int_{p}^{p_0}\frac{dp}{p} = A(\log_e p_0 - \log_e p) = A\log_e\frac{p_0}{p} \tag{13}$$

$$z = -A\int_{a}^{a_0}\frac{da}{a} = A(\log_e a_0 - \log_e a) = A\log_e\frac{a_0}{a} \tag{14}$$

FIG. 2.



Equations 13 and 14 may be written as follows:

$$\frac{p}{p_0} = e^{-\frac{z}{A}} = 1 - \frac{z}{A} \tag{15}$$

$$\frac{a}{a_0} = e^{-\frac{z}{A}} = 1 - \frac{z}{A} \tag{16}$$

The approximate value of $1 - \frac{z}{A}$ is obtained by developing $e^{-\frac{z}{A}}$ in a series and neglecting all the terms containing $\frac{z}{A}$ higher than the first power, which can be done for moderate heights. Substituting the value of A as given above and passing to common logarithms, equations 13 and 14 reduce to the following:

$$z = 60368 \log\frac{p_0}{p} \tag{17}$$

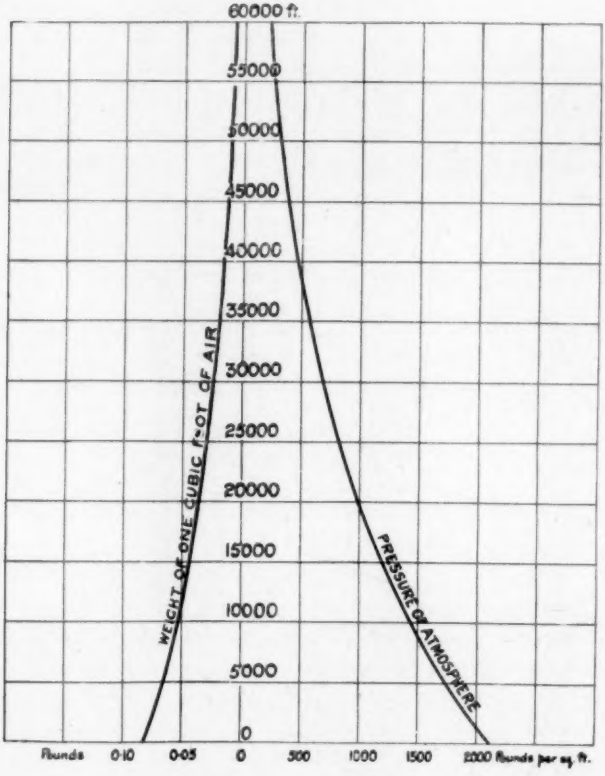
$$z = 60368 \log\frac{a_0}{p} \tag{18}$$

The above formulæ, due to Halley, show that as the height increases in arithmetical progression, the pressure of the atmosphere and the weight of the unit volume decrease in geometrical progression. At a height of 60,368 feet, or 11.43 miles, the pressure is 0.1 that of the surface, and at a height of 22.86 miles the pressure is 0.01 of that of the surface. In general terms for

$$z = 60368\ n,\ p = \frac{1}{10^n}\ p_0.$$

Fig. 3 shows the variation of atmospheric pressure and weight of the unit of volume of air computed from the foregoing

FIG. 3.



formulæ. Both coal gas and hydrogen, the gases employed in ballooning, obey the same laws as air, and the weights of a unit

volume of each of these gases can be computed in exactly the same way as that of the air.

The following table gives the values of z for all values of the ratio $\frac{p_0}{p}$ from 1 to 1,259:

TABLE I

$\frac{p_0}{p}$	z									
	0	1	2	3	4	5	6	7	8	9
1.00	0	26	52	79	105	131	157	184	210	236
1.01	262	285	312	338	364	390	417	443	469	492
1.02	518	545	571	597	623	646	673	699	725	751
1.03	774	800	826	850	876	902	928	951	978	1004
1.04	1027	1053	1079	1102	1129	1156	1178	1204	1230	1253
1.05	1279	1302	1328	1354	1378	1404	1427	1453	1479	1502
1.06	1528	1552	1578	1601	1627	1650	1676	1699	1726	1749
1.07	1775	1798	1824	1847	1870	1896	1919	1945	1968	1994
1.08	2018	2041	2067	2090	2116	2139	2162	2188	2211	2234
1.09	2260	2283	2306	2330	2356	2379	2405	2428	2451	2474
1.10	2500	2523	2546	2572	2595	2618	2644	2667	2690	2713
1.11	2736	2759	2782	2808	2831	2854	2877	2900	2923	2946
1.12	2972	2995	3018	3041	3064	3087	3110	3133	3159	3182
1.13	3202	3228	3251	3274	3297	3320	3343	3366	3389	3412
1.14	3435	3458	3481	3504	3527	3550	3573	3596	3619	3642
1.15	3665	3688	3711	3734	3757	3777	3800	3823	3846	3869
1.16	3891	3914	3937	3960	3983	4006	4026	4049	4072	4095
1.17	4117	4140	4163	4186	4209	4232	4255	4275	4298	4321
1.18	4341	4361	4384	4407	4429	4452	4472	4495	4518	4538
1.19	4560	4583	4606	4626	4649	4672	4692	4715	4737	4757
1.20	4780	4803	4823	4846	4869	4888	4911	4934	4954	4977
1.21	5000	5023	5043	5066	5089	5112	5135	5155	5178	5198
1.22	5213	5236	5259	5279	5290	5321	5338	5364	5384	5407
1.23	5426	5449	5469	5492	5512	5535	5555	5577	5597	5620
1.24	5640	5660	5683	5703	5723	5745	5768	5788	5808	5828
1.25	5850	5873	5893	5913	5936	5955	5975	5995	6017	6037

An example will show the use of this table. Required the difference in altitude between two stations when the barometer reading at the lower station is 29.921 and the upper station 28.640. The ratio of the readings is 1.045, and, entering the table with this ratio, we find the difference in altitude to be 1,156 feet. (NOTE.—If the readings are obtained by use of the mercurial barometer, these readings should be corrected for temperature; if obtained by an aneroid barometer, no correction is necessary for temperature.)

In the foregoing discussion the temperature has been considered uniform throughout the air column and no account has

been taken of the geographical position, the effect of the change of the force of gravity due to altitude, or the hydroscopic state of the atmosphere. Under ordinary conditions the thermometer in this latitude falls as the height increases at an average rate of about three degrees per thousand feet. Owing to the motion of vertical currents in the air, the distribution of heat is very unequal, and it is practically impossible to predict in advance the temperature that will be encountered at any elevation above the surface of the ground. While Halley's formula may be considered sufficiently accurate for practical purposes up to about 5,000 feet, for heights greater than this the effects of the temperature variation and force of gravity due to the elevation of the lower station above sea level and the hydroscopic state of the atmosphere must be taken into consideration. The limits of this paper do not permit the presentation of La Place's solution of the problem. It is to be noted that La Place's formula, in a very convenient shape, is to be found in the Smithsonian Meteorological Tables, which should be used when a considerable degree of accuracy is desired.

The ascensional force or the lifting power of a gas is the difference between the weight of a unit volume of air and a unit volume of gas. Calling f_g the ascensional force of the gas, we have

$$f_g = a - b = a(1 - d) \qquad (19)$$

If V is the volume of a balloon completely full of gas whose ascensional force is f_g, the total ascensional force of the gas or the total weight that the gas can lift is

$$F = Vf_g = V(a - b) = Va(1 - d) = V(a_o - b_o)\frac{p}{p_o} = F_o\frac{p}{p_o} \qquad (20)$$

It is evident from equation 20 that for balloons of equal volume, the balloon filled with the lighter gas will have the greater total ascensional force or will lift the greater weight. The two gases used in ballooning are hydrogen and coal gas, whose densities can, for practical purposes, be assumed as 0.12 and 0.42 respectively. The ascensional force f_g of hydrogen becomes 0.071 lb. and for coal gas 0.044 lb. The total ascensional force of a balloon of V capacity at start, when filled with hydrogen is

$$F_o = 0.071\,V \tag{21}$$

and for coal gas

$$F_o = 0.046\,V \tag{22}$$

No matter how impermeable the envelope of a balloon may be, there is always the greatest difficulty in keeping it in the air for any considerable period of time, owing to its vertical instability. This instability is due to the variations in the temperature and pressure at different heights, alternations of sun and shade due to clouds, to passage through warmer or colder strata, to rain, dew or snow, causing expansion or contraction of the gas, or changes in the weight of the balloon. When in the air a balloon acts like a submerged submarine boat which sinks to the bottom or rises to the surface of the water unless held in position by the use of ballast. If the boat in its forward movement encounters warmer or colder strata in the water, it sinks or rises unless water ballast is pumped out or in, and is never for any length of time in a state of equilibrium between the bottom and the surface of the water. A balloon is at rest only on the surface of the earth or in a zone of equilibrium.

A balloon can be in one or two states, either completely or partially inflated. In the former state its volume is constant and its weight variable, while in the latter its weight is constant and its volume variable. When a completely inflated balloon ascends, the atmospheric pressure diminishes and the gas in the envelope expands, escaping through the sleeve of the appendix, which is always open. The envelope remains full and the volume constant so long as the balloon is rising or is in a zone of equilibrium. When the balloon begins to descend, the increase of pressure contracts the volume of the gas and, as the gas and air are at the same pressure, due to the open appendix, no air will enter the envelope which contracts, the weight of the gas remaining unchanged.

For a balloon of constant volume V, let W be equal to the weight of the air displaced. The ratio of the weight of the air displaced at sea level to that at any altitude will be

$$\frac{W_o}{W} = \frac{Va_o}{Va} = \frac{a_o}{a}$$

and by using equation 18 we have

$$z = 60368 \log \frac{W_o}{W} \tag{23}$$

from which the weight of the air displaced at any altitude may be calculated. If the gas filling the balloon is at the same temperature as that of the air surrounding it, its variation of weight at different altitudes obeys the same law as the variation of the weight of the air. The total ascensional force of the gas filling the envelope is readily obtained by taking the difference between the weights of the air and the gas at various altitudes.

At the aëronautical station of the Signal Corps at Fort Omaha, two sizes of balloons are usually employed, one of 19,000 cubic feet and the other of 35,000 cubic feet capacity, and hydrogen is used to inflate them. The weights of the air displaced by these two sizes of balloons, together with the weights of the hydrogen and coal gas filling them, have been computed and are plotted in Fig. 4, together with the total ascensional force of the gas in each case.

When the balloon has been inflated, put on its feet, and the passengers, instruments and ballast are in the basket ready for ascension, the balloon is weighed; that is, ballast is either taken from or added to the basket until the balloon, when lifted from the ground, neither rises nor falls. If, after having been weighed, an amount of ballast is then put overboard, the balloon will rise until the total weight of the balloon is equal to the weight of the volume of air displaced, when, in accordance with the principle of Archimedes, its vertical motion will cease. It is then in a position or zone of equilibrium. The amount of ballast put overboard on starting is called the starting ballast or initial rupture of equilibrium. After the balloon has been weighed before starting, its total weight is then equal to the weight of the air displaced. The total weight of the balloon is made up of the weight of the gas filling the envelope and the solid weight of the balloon. The solid weight of the balloon is made up of the weight of all its parts, the weight of the passengers, instruments and impedimenta and ballast in the basket, and at start, in addition to these, the starting ballast.

The ascensional force of the balloon at any point is the difference between the weight of the air displaced by the balloon and the total weight of the balloon or the difference between the total ascensional force of the gas and the solid weight of the balloon. Calling the ascensional force of the balloon Φ and the solid weight w, we have

$$\Phi = F - w = F_0 \frac{p}{p_0} - w = F_0\left(1 - \frac{z}{A}\right) - w \qquad (24)$$

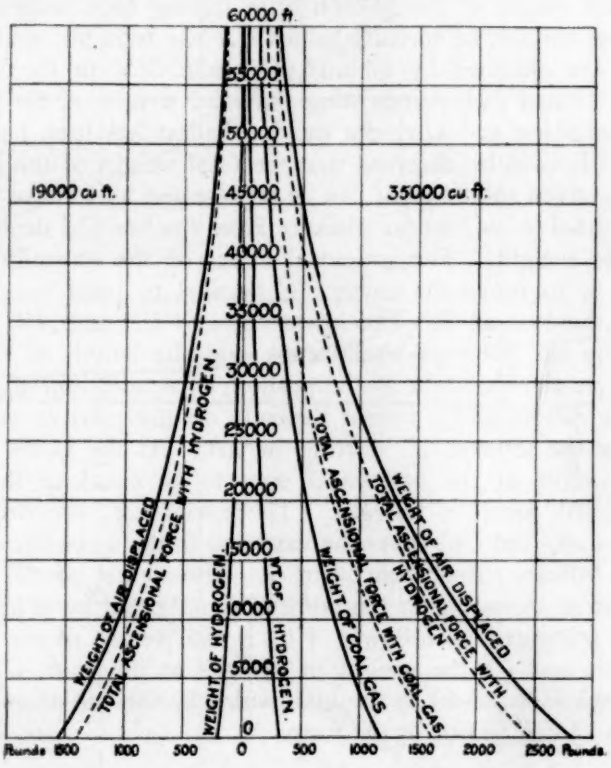
At start we have

$$f = F_0 - w \qquad (25)$$

f being the initial rupture of equilibrium.

When the balloon is in equilibrium, its ascensional force is zero, and we have from equation 24 the condition for

FIG. 4.



equilibrium that the solid weight is equal to the total ascensional force of the gas or, what is the same thing, the total weight is equal to the volume of the air displaced.

The height of the zone of equilibrium which a balloon will

reach with a given amount of starting ballast can be determined graphically by the method of Captain Barthes.

If the curve of the weight of the air displaced by the balloon and the curve of the total weight of the balloon for a given amount of starting ballast be plotted, and they intersect, their point of intersection gives the height of the position of equilibrium. In Fig. 5, the curves AB, the weight of the volume of air displaced, NM, the weight of the hydrogen filling the balloon, and HI, the total ascensional force of the hydrogen, are taken from Fig. 4. The curves AC' and CD represent the total weight of the balloon after having been weighed and after the amount of starting ballast CA has been put overboard. These are obtained by adding the curve MN to the vertical lines $F'E'$ and FE, representing the solid weight of the balloon after weighing and after the starting ballast has been put overboard. It is to be observed that the total weight of the balloon for any given solid weight can be represented by a curve similar and parallel to AC' whose distance from the line OZ depends on its solid weight. The graphical effect of the expenditure of ballast is to move the curve AC parallel to itself nearer and nearer the axis of Z. The intersection of CD and AB at G is evidently the point of equilibrium, and the length of the line GG' gives the elevation of the position of equilibrium above the starting point. This height depends on the relative value of CA, or the amount of starting ballast. At the point G, the solid weight of the balloon is seen to be equal to the total ascensional force of the gas. The curve LK, the difference between AG and CG, gives the variation in the ascensional force of the balloon rising from A to G. The weight of the hydrogen lost in ascending to the point G is indicated by $G'C$, which can be computed as follows: Vb_0 is the weight of the gas at the start and Vb the weight of the gas at the point G; their difference $V(b_0 - b)$ is the loss, which by the use of equations 20 and 15 can be put in the form

$$\frac{F_0}{A} \cdot \frac{d}{1-d} \cdot z \qquad (26)$$

Applying this formula to the 19,000 and 35,000 cubic foot balloons filled with hydrogen, the loss of the hydrogen in pounds is 0.0007 z and 0.0015 z, respectively.

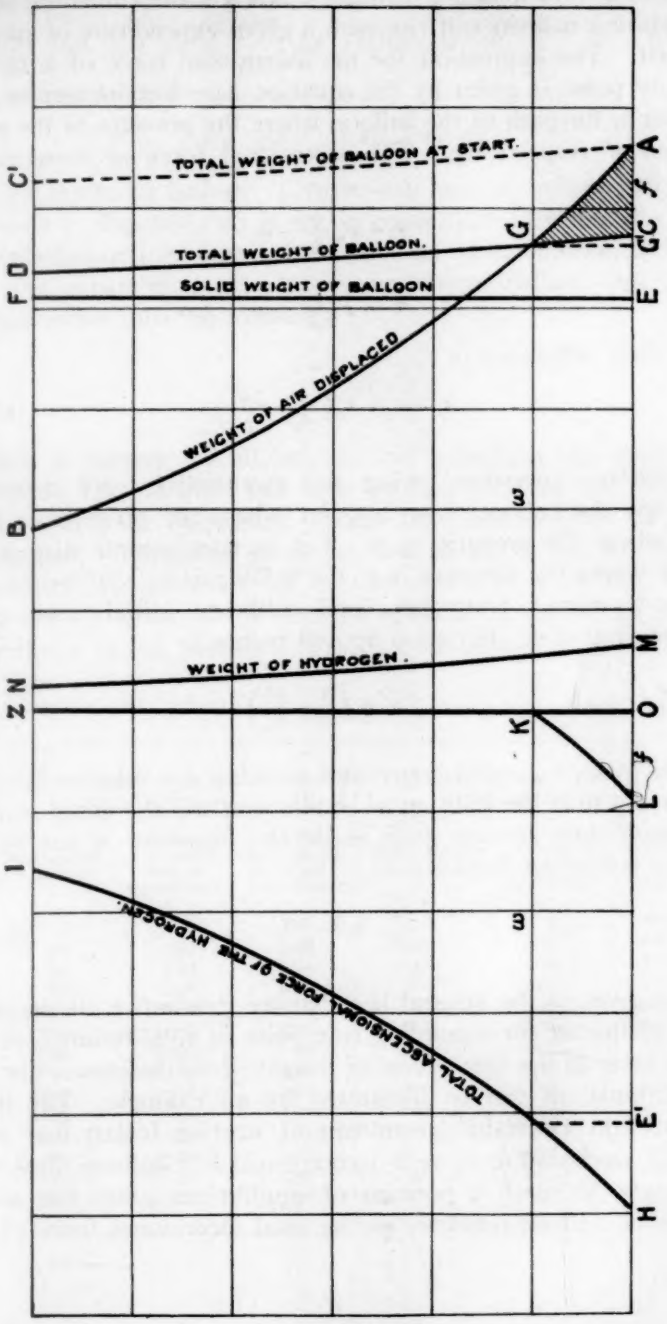

TOTAL WEIGHT OF BALLOON AT START.
TOTAL WEIGHT OF BALLOON.
SOLID WEIGHT OF BALLOON
WEIGHT OF AIR DISPLACED
WEIGHT OF HYDROGEN.
TOTAL ASCENSIONAL POWER OF THE HYDROGEN.
A
C'
G
C
F
D
E
B
M
N
O
K
L
I
H
E'

FIG. 5.

Let us now obtain a formula which will determine the height to which a balloon will rise with a given expenditure of starting ballast. The expression for the ascensional force of a balloon at any point is given by the equation 24. Let us assume two points in the path of the balloon where the pressure of the air is p and p' respectively. The ascensional force at these points will be

$$\Phi = F_o \frac{p}{p_o} - w$$

$$\Phi' = F_o \frac{p'_o}{p} - w$$

and their difference is

$$\Phi - \Phi' = F_o \left(\frac{p}{p_o} - \frac{p'}{p_o} \right) \qquad (27)$$

this latter expression giving the ascensional force necessary to raise the balloon from a point where the pressure is p to one where the pressure is p'. Let us now assume that at the point where the pressure is p' the balloon is in equilibrium and that it started from sea level with an initial rupture of equilibrium of f. Equation 27 will reduce to

$$f = F_o \left(1 - \frac{p'}{p_o} \right) \qquad (28)$$

which gives a general expression showing the relation between the pressure at the position of equilibrium and the initial rupture of equilibrium at start from sea level. Equation 28 can be put in the following form:

$$\frac{f}{F_o} = \frac{p_o - p'}{p_o} \qquad (29)$$

which gives us the general law that the diminution of the pressure of the air corresponding to a point of equilibrium is in the same ratio as the diminution of weight of the balloon. The use of formula 28 can be illustrated by an example. Let it be required to ascertain the amount of starting ballast that must be put overboard to cause a 19,000 cubic foot balloon filled with hydrogen to reach a position of equilibrium 4,800 feet above sea level. From equation 21 the total ascensional force of the

hydrogen at sea level is 1350 pounds, and from Table I, for 4,800 feet the ratio $\frac{p'}{p_o}$ (the reciprocal of $\frac{p_o}{p'}$) is 0.83 and equation 28 becomes

$$f = 1350\,(1 - 0.83) - 230 \text{ lbs.},$$

or 5¾ sacks of ballast. (NOTE.—A sack of ballast weighs 40 pounds.) Equation 28 is not in convenient form for the direct calculation of the height of the position of equilibrium produced by the expenditure of a given amount of ballast, but can be transformed into the following:

$$z = A \frac{f}{F_o - \frac{f}{2}} \qquad (30)$$

which is correct for all heights that a balloon can reach with safety. This formula has been used to compute the following ballast table for 19,000 and 35,000 cubic foot balloons filled with hydrogen. The table gives the heights above sea level of the positions of equilibrium for various amounts of starting ballast and the elevation of the zone of equilibrium caused by the expenditure of 20 pounds (½ sack) of ballast at the different heights.

TABLE II.

19,000-cubic-foot balloon filled with hydrogen.			35,000-cubic-foot balloon filled with hydrogen.		
Starting ballast, pounds.	Feet above sea level in zone of equilibrium	Rise in feet for 20 pounds of ballast expended.	Starting ballast, pounds.	Feet above sea level in zone of equilibrium.	Rise in feet for 20 pounds of ballast expended.
0	0	390	0	0	210
20	390	410	20	210	215
40	780	410	40	425	215
60	1190	410	60	640	215
80	1600	420	80	855	215
100	2020	420	100	1070	215
120	2440	430	120	1285	220
140	2870	430	140	1505	220
160	3300	440	160	1725	220
180	3740	450	180	1945	230
200	4190	460	200	2175	230
220	4650	460	220	2405	240
240	5110	470	240	2645	240
260	5580	470	260	2885	250

An example will illustrate the use of the foregoing table. The pilot of a 19,000 cubic foot hydrogen balloon in equilibrium at 1,550 feet is approaching a range of hills whose summit he discovers from his map is 2,500 feet above him. How much ballast should he put overboard to clear the range? To clear the range he should figure on ascending 2,700 feet, 200 feet being added as a margin of safety. The table shows that at a height of 1,600 feet 20 pounds of ballast will raise him 420 feet, and by simple proportion he ascertains that 128 pounds, or 3¼ sacks of ballast, will carry him to the desired altitude.

The ballast formula has been deduced under the supposition that the temperature of both the air and the gas is 32° F., and that the temperature does not change as the balloon rises. As a rule, the temperature of the air will fall as the balloon rises, and, moreover, the air and gas are usually at different temperatures; in fact, in some ascensions a difference of 50° F. has been found to exist between the temperature of the gas and that of the air. The values given in Table II are only approximate and should be corrected by the following considerations. When the temperature of the air and the gas remain the same, the height of the zone of equilibrium for a completely-filled balloon will be increased or diminished by 50 feet for each degree that the temperature of the air is diminished or increased, and this variation in the position of the zone of equilibrium is independent of the size and altitude of the balloon or the nature of the gas filling it. When the air and the gas are not at the same temperature, the zone of equilibrium is raised for each degree F. that the temperature of the gas exceeds that of the air by about 36 feet, if the balloon is filled with coal gas, and by about 6 feet if filled with hydrogen. A balloon filled with coal gas is about six times more sensitive to changes of temperature than one filled with hydrogen. A rise in the temperature of the gas over that of the air, caused, for example, by the passage from shadow to bright sunshine, will produce an elevation of the zone of equilibrium as though an amount of ballast had been put overboard, and the increase in altitude is independent of the volume of the balloon, but depends upon the nature of the gas used, it being greater for the denser gas.

Fig. 6 shows the result of expending ballast when a balloon is in equilibrium at different points above the ground.

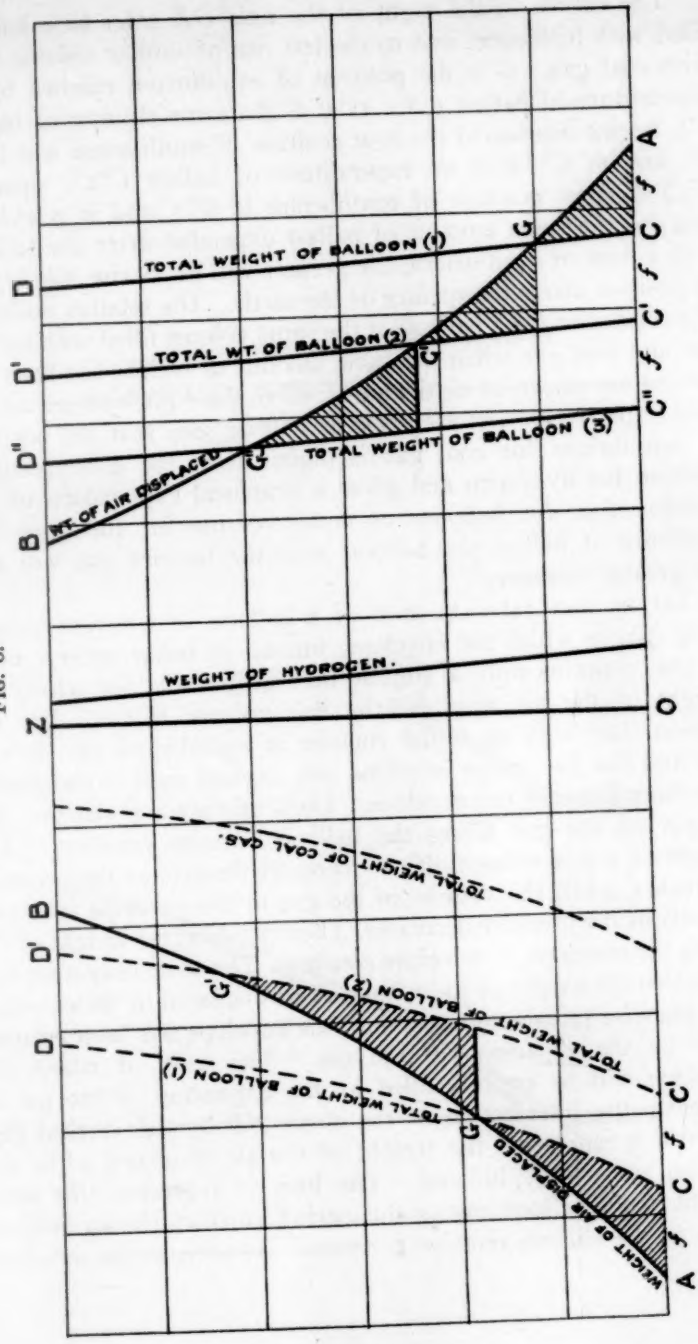

TOTAL WEIGHT OF BALLOON (1)
TOTAL WT. OF BALLOON (2)
TOTAL WEIGHT OF BALLOON (3)
WT. OF AIR DISPLACED
WEIGHT OF HYDROGEN.
TOTAL WEIGHT OF COAL GAS.
TOTAL WEIGHT OF BALLOON (1)
TOTAL WEIGHT OF BALLOON (2)
WEIGHT OF AIR DISPLACED
A
C
C'
C''
D
D'
D''
B
Z
O

FIG. 6.

The curves to the right of the axis OZ refer to a balloon filled with hydrogen, and to the left one of similar volume filled with coal gas. G is the position of equilibrium reached by an expenditure of ballast CA. If at G the same amount of ballast $C'C$ be put overboard the new position of equilibrium will be at G', and at G', with an expenditure of ballast $C''C'$, equal to $C'C$, the new position of equilibrium is G''; and it is evident that for the same amount of ballast expended after the balloon is in a zone of equilibrium, the greater will be its rise, the higher its position above the surface of the earth. The relative positions of equilibrium for a balloon of the same volume filled with hydrogen and coal gas when the same amount of ballast has been expended are shown at G, G and G', G' to the right and left of the axis respectively. In each case it will be seen that the position of equilibrium for coal gas is higher than the corresponding position for hydrogen and gives a graphical explanation of the paradox that for balloons of equal volume for the same expenditure of ballast the balloon with the heavier gas will rise the greater distance.

Let us now take the case of a balloon of constant weight (Fig. 7), in which the envelope, instead of being entirely filled by gas, contains only a volume that weighs Fc, for which the weight of the air displaced by this volume is Oa. Let the balloon start with an initial rupture of equilibrium ca. It will rise and the gas in the envelope will expand until it completely fills the volume of the envelope. Until this point is reached, the weight of the gas filling the balloon remains constant. The weight of a unit volume of gas decreases directly as the pressure decreases, while the volume of the gas in the envelope increases directly as the pressure decreases. Their product, the weight of the gas in the envelope, is therefore constant. The same reasoning will show that the weight of the volume of air displaced by the envelope will likewise remain constant until the envelope has been entirely filled by the expansion of the gas. The point at which the envelope will be entirely filled by the expansion of the gas is evidently the intersection of the curve AB by the vertical line aa', which represents the weight of the air displaced while the balloon is partially inflated. The line cc' represents the solid weight of the balloon during this period in which the ascensional force of the balloon remains constant. As soon as the envelope

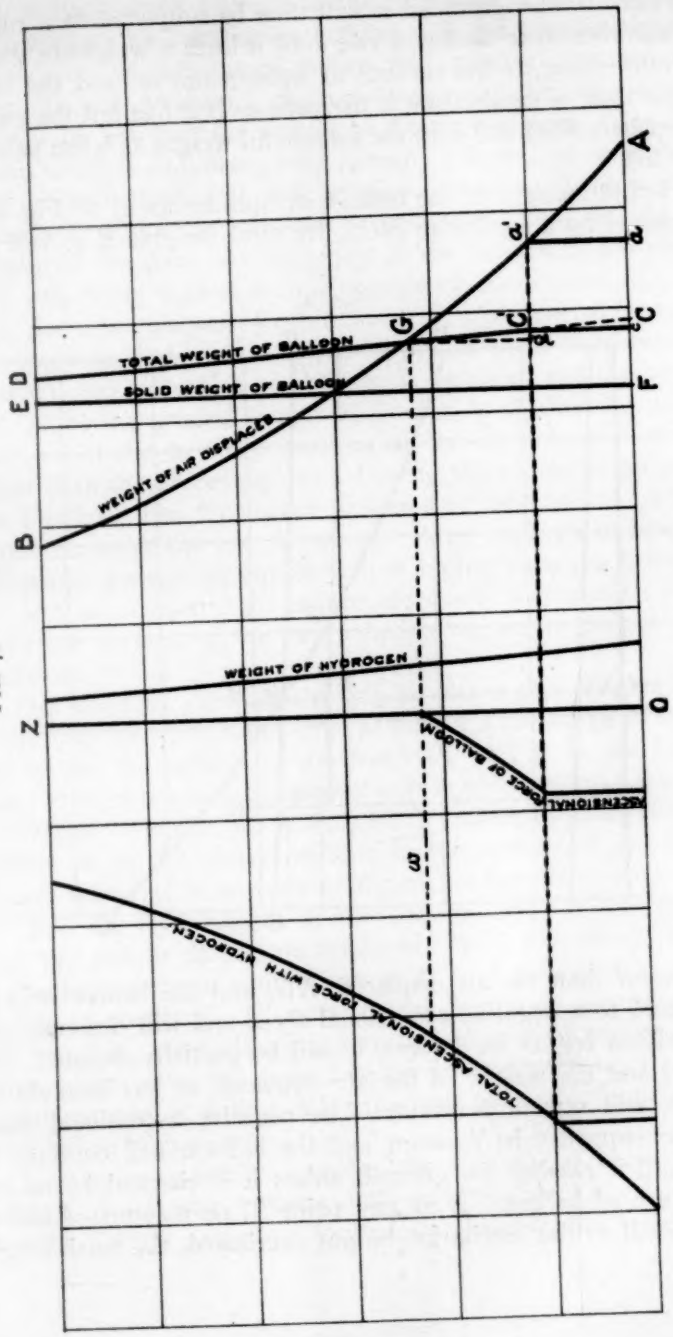
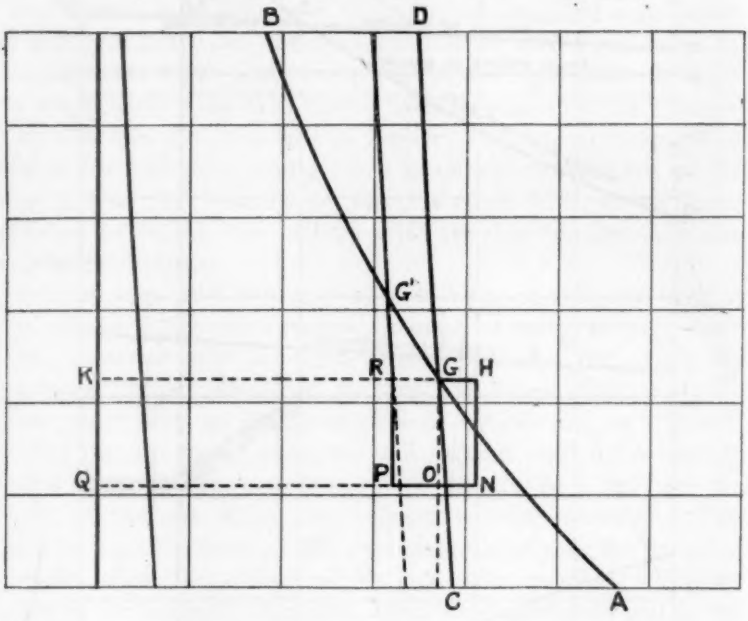

A
a
C
c
G
E
D
TOTAL WEIGHT OF BALLOON
SOLID WEIGHT OF BALLOON
F
B
WEIGHT OF AIR DISPLACED
WEIGHT OF HYDROGEN
Z
Q
ASCENSIONAL FORCE OF BALLOON
ASCENSIONAL FORCE
3
TOTAL ASCENSIONAL FORCE WITH HYDROGEN

FIG. 7.

has been completely filled it will then be subjected to a rupture of equilibrium cc' and will rise until it loses a weight of gas gc' corresponding to the rupture of equilibrium cc' and the height of the zone of equilibrium is the same as if it had left the ground completely filled and with the same solid weight as when partially inflated.

Let the weight of the balloon in equilibrium at G, Fig. 8, be increased by a surcharge HG. Its total weight, KH, will now

FIG. 8.



be greater than the air displaced, KG, and the balloon will be subjected to a negative ascensional force and will descend. As the balloon begins its descent, it will be partially deflated. Its weight and the weight of the air displaced, as has been shown before, will remain constant. The negative ascensional force will consequently be constant and the balloon will continue to fall until it reaches the ground, unless it is checked by an expenditure of ballast. If at any point N an amount of ballast NO, equal to the surcharge, be put overboard, the total weight

of the balloon and the weight of the air displaced are then equal, but, owing to its inertia, the balloon will continue its descent. If, however, an amount of ballast *PN*, greater than the surcharge, be put overboard, the total weight of the balloon, *PQ*, will now be less than the weight of the air displaced, *OQ*. The balloon will rise and, being only partially inflated, the ascensional force of the balloon, *PO*, will remain constant until the point *R* is reached, where the envelope is completely filled by the expansion of the gas. At the point *R* the balloon is completely filled and, being subjected to a rupture of equilibrium *RG*, will reach the new position of equilibrium *G'*. In general terms we may conclude that when a balloon descends (it is then partially inflated), the rupture of equilibrium is constant, and the balloon will fall to the ground unless its descent is checked by ballast, when it will rise to a new position of equilibrium which will be higher than the preceding one. During the course of an ascension a balloon has a constant tendency to descend, which must be overcome by the use of ballast. After each expenditure of ballast the position of equilibrium is higher than the preceding one, so that in general the balloon constantly increases its height above the surface of the earth during the entire course of an ascension.

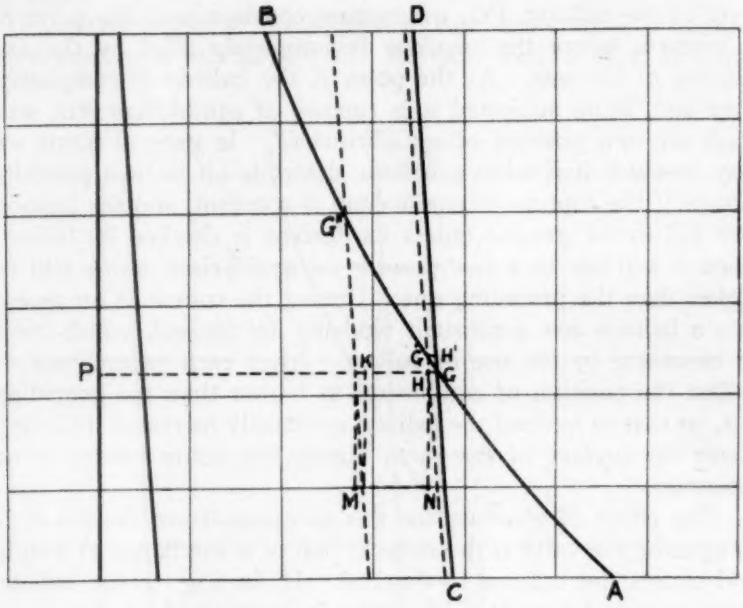
The effect of allowing the gas to escape from the envelope by opening the valve is the same as that of a surcharge of weight and causes the balloon to descend. If, in Fig. 9, the balloon being in equilibrium at *G*, the valve is opened and an amount of gas whose weight is *HG* is allowed to escape, the weight of the volume of air *KG* corresponding to the volume of gas lost is greater than *HG* on account of the higher specific gravity of the air, and the total weight of the balloon, *PH*, is then greater than the weight of the air displaced, *PK*. The effect is as if the balloon were in equilibrium at *G'* and subjected to a surcharge of weight *G' H'* equal to the weight of the volume of gas lost. If, after allowing a certain weight of gas to escape through the valve, the descent of the balloon is checked as at *N* by an amount of ballast *NM*, the new position of equilibrium *G''* is much higher.

Let us now briefly consider the velocity of motion of a balloon of constant volume, following the method of Colonel Renard. While ascending to moderate heights, the mass of the

balloon can be considered constant, as the mass of the gas lost is a very small percentage of the total weight of the balloon.

The balloon is subjected to the action of two forces, one acting vertically upwards, the ascensional force of the balloon,

FIG. 9.



and the other vertically downward, the resistance of the air. The resistance of the air can be expressed as follows:

$$R = kv^2$$

While the coefficient k varies with the height of the balloon, for practical purposes it can be considered constant and defined by the relation

$$k = 0.000424D^2$$

D being the diameter of the balloon in feet. If m is the mass of the balloon and v its velocity, the resultant force acting is

$$m\frac{dv}{dt} = \Phi - kv^2 \qquad (31)$$

From equations 24 and 25 we have

$$\Phi = f - \frac{F_o}{A} z$$

and placing this value in 31, we have

$$m \frac{dv}{dt} = f - \frac{F_o}{A} z - kv^2 \qquad (32)$$

as the general equation of the motion of the balloon. Equation 32 can easily be placed in the form of a lineal differential equation of the first degree whose integral is

$$kv^2 = f + \frac{mF_o}{2kA} - \frac{F_o}{A} z + Cke^{-\frac{2k}{m} z} \qquad (33)$$

Let $\beta = \frac{m}{2k}$ and introducing this into equation 33, we have the general expression

$$kv^2 = f + \frac{F_o}{A} \beta - \frac{F_o}{A} z + Cke^{-\frac{z}{\beta}} \qquad (34)$$

The constant of integration C is defined by the conditions at start, where both v and z are zero, and from 34

$$Ck = -\left(f + \frac{F_o}{A} \beta\right)$$

Substituting this in equation 34, the equation finally reduces to the form of

$$kv^2 = \left[f - \frac{F_o}{A}(z - \beta)\right] - \left(f + \frac{F_o}{A} \beta\right) e^{-\frac{z}{\beta}} \qquad (35)$$

which gives us a general expression for the velocity of the balloon at a point z feet above starting point. It is to be seen from 35 that the velocity depends on two terms, one lineal and the other exponential. To see the effect of the exponential term, let us take the case of a 19,000 foot hydrogen balloon starting with an initial rupture of equilibrium of 100 pounds. For this balloon $F^\circ = 1{,}350$ pounds, $\beta = 48$ feet, and $k = 0.464$. With these values we have the following table:

z	β	2β	3β	4β	5β
$e^{-\frac{z}{\beta}}$	0.368	0.135	0.50	0.018	0.0067
$f-\frac{F_0}{A}(z-\beta)$	100.0	98.5	97.0	95.5	93.0
$\left(f+\frac{F_0}{A}\beta\right)e^{-\frac{z}{\beta}}$	38.0	14.0	5.0	1.8	0.7
kv^2	62.0	84.5	92.0	93.7	92.3
v	11.56	13.49	14.07	14.21	14.08

From this table it is to be seen that the velocity rapidly increases to a maximum, and, after passing the maximum, slowly diminishes. The effect of the exponential term can be neglected after the balloon has reached a height of about 200 feet. Neglecting this term, the general expression for the velocity reduces to the form

$$kv^2 = f - \frac{F_0}{A}z + \frac{F_0}{A}\beta \tag{36}$$

If the value of kv^2 be substituted in equation 32, it will reduce to the following:

$$m\frac{dv}{dt} = -\frac{F_0}{A}\beta \tag{37}$$

from which it will be seen that during this period of the balloon's motion the resultant force acting on the balloon is constant and the velocity is uniformly retarded. The value of the term $\frac{F_0}{A}\beta$ is so small that it can be neglected, and we have

$$kv^2 = f - \frac{F_0}{A}z \tag{38}$$

or

$$v = \sqrt{\frac{f}{k} - \frac{F_0}{Ak}z} \tag{39}$$

as a general expression for the velocity of the balloon at the point z. If we neglect the second term under the radical, which can be done for all portions of the balloon's passage except the last, we have the expression

$$v' = \sqrt{\frac{f}{k}} \tag{40}$$

which is known as the velocity of regimen. From the above expressions it is to be seen that the motion of the balloon can be divided into three periods: the first, or starting period, in which the effect of the exponential term is felt, the velocity rapidly increasing to a maximum about 200 feet above the start; the second period, or the period of regimen, in which the motion of the balloon is uniformly retarded and its velocity approximately equal to the velocity of regimen and the resistance of the air almost equal to the ascensional force of the balloon; and the third or last period, in which the effect of the term $\frac{F_o}{Ak} z$ is felt. During this period the balloon comes slowly to rest.

Let us now investigate the time element. If z' be the altitude of the zone of equilibrium for a balloon whose total ascensional force is F_o and initial rupture of equilibrium is f, we have from equation 28:

$$z' = A \frac{f}{F_o} \text{ or } \frac{F_o}{A} = \frac{f}{z'} \tag{41}$$

Substituting this value in equation 38, we have

$$kv^2 = f\left(1 - \frac{z}{z'}\right) \tag{42}$$

Since $v = \frac{dz}{dt}$, equation 42 reduces to the form

$$\frac{dz}{dt} = \sqrt{\frac{f}{k}} \cdot \sqrt{1 - \frac{z}{z'}} = v' \sqrt{1 - \frac{z}{z'}} \tag{43}$$

or,

$$dt = \frac{1}{v'} \frac{dz}{\sqrt{1 - \frac{z}{z'}}} \tag{44}$$

and integrating, we have

$$t = -\frac{2z'}{v'} \sqrt{1 - \frac{z}{z'}} + C. \tag{45}$$

The constant of integration C is defined by the conditions at start, where both t and z are zero, and from 45 we have

$$C = \frac{2z'}{v'}$$

Substituting this value of C, equation 45 reduces to

$$t = \frac{2z'}{v'}\left(1 - \sqrt{1 - \frac{z}{z'}}\right) \qquad (46)$$

which is the general expression for the time that the balloon will take to reach the altitude z. To ascertain the time required to reach a zone of equilibrium, put z equal to z' in the foregoing formula, which will reduce to

$$t = \frac{2z'}{v'} \qquad (47)$$

Just before coming to rest the motion of the balloon is very slow. It is interesting to compare the time that it will take a balloon to travel a given height with the time that it takes to reach its position of equilibrium. Let us make z in equation 46 equal $\frac{9}{10}z'$, and we have

$$t' = \frac{2z'}{v'}\left(1 - \frac{1}{\sqrt{10}}\right) = 1.4\,\frac{z'}{v'} \qquad (48)$$

from which we readily see that $\frac{t'}{t} = \frac{2}{3}$, approximately, or the time to travel the last tenth of the distance from the start to position of equilibrium is one-third of the total time of travel of the balloon.

The following table gives the height of the position of equilibrium, the velocity of regimen, the time required to reach the position of equilibrium in seconds, the time to travel $\frac{9}{10}$ of this course, together with the average velocity in feet per second, for both the 19,000 foot and 35,000 foot balloons:

TABLE III.

Starting ballast, lbs.	Height of point of equilibrium.	Velocity of regimen, feet per second.	Time required to reach equilibrium, seconds.	Nine-tenths of course.	Average velocity feet per second.
	z	v'	t	t'	
19000 FT. BALLOON.					
20	390	6.5	120	85	4.6
40	780	9.2	170	120	6.5
60	1190	11.3	210	145	8.2
80	1600	13.1	245	170	9.4
100	2020	14.6	275	195	10.3
20	2440	16.0	305	210	11.6
40	2870	17.3	330	230	12.4
60	3300	18.5	355	250	13.2
80	3740	19.7	380	265	14.1
200	4190	20.7	405	280	15.0
20	4650	21.7	430	300	15.5
40	5110	22.7	450	315	16.0
35000 FT. BALLOON.					
20	210	5.3	80	60	3.5
40	425	7.5	115	80	5.3
60	640	9.2	140	100	6.4
80	855	10.7	160	110	7.7
100	1070	11.9	180	125	8.6
20	1285	13.1	200	140	9.2
40	1505	14.1	215	150	10.0
60	1725	15.1	230	160	10.7
80	1945	16.0	245	170	11.4
200	2175	16.9	260	180	12.1
20	2405	17.7	270	190	12.7
40	2645	18.5	280	200	13.2

In case the balloon leaves the ground only partially inflated, the ascensional force remains constant until the envelope is completely filled by the expansion of the gas and is equal to the initial rupture of equilibrium. Under this condition the general equation of the motion of the balloon becomes

$$m\frac{dv'}{dt} = f - kv'^2 \qquad (49)$$

The integral of this equation is

$$Ce^{-\frac{z}{\beta}} = f - kv'^2 \qquad (50)$$

C being the constant of integration and $\beta = \frac{m}{2k}$

At start z' and v' are both zero and $C = f$. Introducing this value in equation 50, it reduces to the form of

$$v'^2 = \frac{f}{k}\left(1 - e^{-\frac{z}{\beta}}\right) \qquad (51)$$

The value $e^{-\frac{z}{\beta}}$ rapidly approaches zero and in a very short time after starting we have $v' = \sqrt{\frac{f}{k}}$, the velocity of regimen.

For the partially-inflated balloon its motion can be divided into two periods: the first, or starting period, in which the velocity very quickly reaches the velocity of regimen; and the second period, in which the velocity is constant and equal to the velocity of regimen. If z' is the height of the zone of equilibrium, the time to reach this height can be expressed as follows:

$$t' = \frac{z}{v'} \qquad (52)$$

Comparing this expression with equation 47, we see that $t = 2t'$, or that a completely-inflated balloon requires double the time to reach the same zone of equilibrium that it would reach if partially inflated at start with the same rupture of equilibrium; in other words, for the same rupture of equilibrium, a completely-filled balloon moves more slowly than a partially-inflated one.

When descending, a balloon is only partially inflated, and its velocity, the velocity of regimen, is constant and depends on the surcharge or negative rupture of equilibrium to which it has been subjected. To make a perfectly safe landing, the velocity of regimen should not exceed six or seven feet per second, which for a 19,000 foot balloon corresponds to a rupture of equilibrium of 20 pounds. If the velocity of descent exceeds the above rate, the fall should be checked by putting overboard in succession about 2½ pounds of ballast for each 100-foot descent of the 19,000 foot balloon and 4½ pounds of ballast for the 35,000 foot balloon, until the motion has slowed down to the desired rate. The amount of ballast to be reserved for a descent depends upon a number of varying factors, such as the size of the balloon, difference in temperature between the ground and the point where balloon is situated, character of

the ground, the velocity of surface wind, etc. It is impracticable to obtain a general expression covering the amount of ballast that should be reserved for the final descent. A safe rule, however, is to keep a full sack of ballast for the actual landing and to start the descent for landing when there remains in addition to this sack an amount of ballast equal to 15 pounds for each 1000 feet of elevation of the 19,000 foot balloon and 20 pounds for the 35,000 foot balloon.

The following important practical rules result from the foregoing discussion:

1. *The balloon should be completely inflated before departure.* The duration of an ascension, other things being equal, depends upon the amount of ballast that can be carried. When the balloon is completely filled, its lifting power is greater, and it will consequently take up more ballast than when partially inflated.

2. *The amount of ballast used at start should be as small as possible and just sufficient to clear obstacles.* Whenever ballast is put overboard, a position of equilibrium is reached, and, as the height of the position of equilibrium is constantly increasing during the progress of the ascension, the lower the initial position of equilibrium at start, the longer the balloon will remain at moderate heights.

3. *The tendency to descend should be checked as soon as possible.* When the balloon descends it acquires velocity, to overcome which requires a greater amount of ballast the greater the velocity. The new position of equilibrium to which the balloon will rise after its downward motion has been checked is higher than the former position of equilibrium and in proportion to the amount of ballast expended.

4. *Ascensional tendencies should never be checked.* To stop a balloon from rising, the valve must be opened and gas lost. This operation causes the balloon to descend. To check the descent, ballast must be expended with an increase in elevation, the object sought to be avoided. The pilot who begins to use his valve cannot remain long in the air.

5. *In landing, unless compelled by a rapid approach to the sea or a large body of water, the descent should be made slowly.* A sack of ballast should be reserved for the landing and the descent begun with a sufficient reserve of ballast.

A New Form of Silica. F. TUCAN. (*Centr. Min.*, 1912, 296.)—In a cave on the island of Brac there was found a secondary lime deposit which contained finely-divided silica, together with sodium chloride and traces of iron, aluminum, and magnesium. After the carbonates were dissolved in hydrochloric acid, the silica formed an impalpable, white dust. Mixed with water it formed a milky liquid which penetrated the best filter paper, and was insoluble even in concentrated alkalies, but soluble in concentrated sulphuric acid. Apparently this was a new form of silica. It is probably of secondary origin, having been precipitated from solution along with the calcium carbonate.

Patents in the United States. B. HERSTEIN. (*J. Ind. Eng. Chem.*, iv, 328.)—A patent for a chemical invention differs from other patents in that an identical product may be obtained by different processes of manufacture, so that infringement of a patented process is not readily detected. Manufacturers sometimes prefer, therefore, to keep new processes secret, and the difficulty is only partially met by the fact that the product itself, if new, may be claimed as the invention. Statistics show that the patent system does not stimulate chemical industries. During the decade 1900–1910, 4,068 patents were issued in the principal chemical industries, and only 38 per cent. of these were issued to persons resident in the United States, as against 88 per cent. for the whole of the patents on all subjects. More chemical patents are issued to German than to American inventors. Out of 1,738 patents in the classes "Carbon Compounds" and "Bleaching and Dyeing Processes," which form the most profitable branches of chemical industry, only 200 were issued to Americans, while 1,247 were issued to Germans, and 844 of these were assigned to four large companies which have an arrangement for the interchange of stock and division of profits, under an agreement lasting till 1954. The foreign inventor prefers to import the article, and is not compelled by law to manufacture in the United States; moreover, the tariff does not affect him, while domestic manufacture is prevented by patent. A compulsory working requirement would be of advantage to chemical industry. It is pointed out that as the result of the new compulsory working requirement in the United Kingdom, up to 1911, 50 foreign firms had begun, or were about to begin, manufacture in England, and that 7,000 hands would be employed; and in addition many licenses have been granted to English manufacturers. The industries affected are mainly in the chemical and allied groups. The fact that a patent is granted in the United States for a new product, apart from the process of manufacture, tends to prevent the introduction of new and better processes for making the same product. Where the patent is for the process only, there is a direct incentive to experiment with the object of obtaining the product by other and better methods.

THE EFFECT OF PIGMENTS UPON THE CONSTANTS OF LINSEED OIL.

BY

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WHEN sealed packages of paints of the cheaper grades are opened after having been stored for a considerable length of time, there is occasionally observed a degree of hardness that renders application difficult. The user is generally at a loss to account for such a condition, inasmuch as the modern metal container is air-tight and has but little room for improvement. The cause of the hardening that has taken place may therefore be assumed to result from certain reactions between the different constituents of the paint. There can be no doubt but that certain kinds of pigments have some influence in the reactions that result in hardening, but the responsibility has been too often placed entirely with the pigment portion of paints. That the oil or vehicle part may have an even more profound relation to the trouble has not been given the consideration it deserves. In support of this statement there is presented herewith evidence of an important nature, in the form of results obtained from the tests described below.

Nearly two years ago the writer carefully prepared a series of paints from various well-known pigments, using as a grinding medium a standard vehicle of pure linseed oil containing neither drier nor thinner of any type. The amount of oil used with each pigment was sufficient to bring the paints in every case to a relative viscosity or body, which was somewhat heavier than is ordinarily used in the application of paints to wooden or metal surfaces. These paints, after preparation, were carefully placed in friction-top tin containers. They were moved about occasionally and were subjected to shipment by freight on two occasions, finally remaining on a shelf in the writer's laboratory for nearly a year previous to examination. Upon removing the lids from the cans there was evidenced, by the appearance of some of the paints, a considerable change of a chemical nature. The writer, attrib-

uting the change that had taken place to a form of saponification, or rather hydrolysis, as such action may be properly termed in the case of paints, was impressed with the opportunity of examining the oil content of the paints, in order to determine whether any marked change had occurred in the constants of the pure linseed oil which was used in their grinding. Fortunately, there was on record the analysis of the oil which had been used for this purpose. The paints were therefore placed individually in two-quart glass jars with a large quantity of a solvent mixture made of 90° benzol and 86° petroleum ether. After the pigment content of the paint had settled out by gravity, the solvent containing the oil in solution was removed by a syphon and subjected to distillation. The temperature of distillation was kept at a point sufficiently high to remove the low boiling point solvent, but not high enough to affect the oil residue. The usual method of oil examination was then followed, many of the determinations being made in duplicate. The results of these tests are given below.

RESULTS OF EXAMINATION OF OILS EXTRACTED FROM PAINTS.

Analysis of oil used in grinding and thinning paints:

Specific gravity	.932
Ash	.190%
Iodine No.	181.
Acid value	2.5

TEST NO. I.

Zinc Oxide.

Condition on Opening.—Paint in excellent condition. Very soft. Some oil of light color floating on top. After extraction with solvent the oil contained fine white zinc of a colloidal nature, which separated out only after several days' standing.

Analysis of extracted oil:

Specific gravity	.9237
Ash	0.36% (white)
Iodine No.	161.
Acid value	3.5

TEST NO. 2.

Corroded White Lead (Basic Carbonate-White Lead).

Condition on Opening.—Paint had thick, wrinkled skin on top, but was in very fair condition. Oil, after extraction, was light colored and clear.

Analysis of oil:

Specific gravity	.9372
Ash	1.149% (light yellow)
Iodine No.	157.5
Acid value	8.6

TEST NO. 3.

Leaded Zinc.

Condition on Opening.—Paint in very good condition. Considerable oil floating on top. Oil, after extraction, was somewhat cloudy, but cleared up after settling for twenty-four hours.

Analysis of oil:

Specific gravity	.9389
Ash	.922% (white)
Iodine No.	157.4
Acid value	5.7

TEST NO. 4.

Corroded White Lead (Basic Carbonate-White Lead)	50%
Zinc oxide	40%
Barytes	10%
	100%

Condition on Opening.—Paint in excellent condition. Some oil floating on top.

Analysis of oil:

Specific gravity	.....
Ash	.674% (light yellow)
Iodine No.	154.1
Acid value	6.7

TEST NO. 5.

Sublimed white lead (basic sulphate-white lead)	60%
Zinc oxide	40%
	100%

Condition on Opening.—Paint in excellent condition. Some oil floating on top.

Analysis of oil:

Specific gravity	.9334
Ash	.626% (white)
Iodine No.	157.8
Acid value	5.6

TEST NO. 6.

Barytes (Barium Sulphate).

Condition on Opening.—Paint settled to a considerable extent. Much clear oil floating on top.

Analysis of oil:

Specific gravity	.9325
Ash	.212% (light)
Iodine No.	160.6
Acid value	3.5

TEST NO. 7.

Silica.

Condition on Opening.—Heavy, viscous oil, resembling a varnish, was floating on a partly-settled mass of pigment. After extraction, the oil held some finely-divided pigment in suspension for some time.

Analysis of oil:

Specific gravity	.9465
Ash	.204% (light)
Iodine No.	149.2
Acid value	8.7

TEST NO. 8.

American Vermilion (Basic Chromate of Lead).

Condition on Opening.—Pigment settled very hard. Oil, after extraction, was dark, but clear.

Analysis of oil:

Specific gravity	.939
Ash	1.271% (yellow)
Iodine No.	156.7
Acid value	8.3

TEST NO. 9.

Red Lead.

Condition on Opening.—Pigment settled very hard. A thick, gelatinous oil floating on top of pigment. Oil, after extraction, was dark brown in color.

Analysis of oil:

Specific gravity	....
Ash	15.56% (light red)
Iodine No.	135.4
Acid value	19.2

TEST NO. 10.

Iron Oxide.

Condition on Opening.—In excellent condition. Very soft, smooth paste. After extraction, the oil was clear, but of a dark red color.

Analysis of oil:

Specific gravity	.9457
Ash	.456% (red)
Iodine No.	156.3
Acid value	8.6

TEST NO. 11.

Carbon Black.

Condition on Opening.—Thin, wrinkled skin on surface. Paste below skin, very soft and smooth. After extraction, the oil was clear and of light color.

Analysis of oil:

Specific gravity	.9356
Ash	.195% (light)
Iodine No.	163.
Acid value	10.5

TEST NO. 12.

Graphite.

Condition on Opening.—Very soft and smooth paste. After extraction, the oil was clear and light in color.

Analysis of oil:

Specific gravity	.....
Ash	.201% (light)
Iodine No.	158.5
Acid value	13.3

These results show that inert pigments such as barytes, iron oxide, graphite and carbon black do not enter into chemical action with linseed oil; the percentage of ash found in the oil extracted from the above pigments being practically identical with the percentage shown by the raw oil. That such pigments may, however, have some physical action upon the oil, that will later develop a chemical change therein, seems evident. The thickened condition of the oil extracted from the silica paint, and the low iodine values and high acid values shown by all of the oils extracted from the above-mentioned inert pigments, would give credence to the above statement.

The pigment that is ordinarily termed American vermilion, the true form of which is a basic chromate of lead, seems to have had no very marked effect upon the oil in which it was ground. It would seem, therefore, that it would prove quite practical to transport this pigment in paste form. On account of its value as a protective of metal, it will probably replace, to some extent, the use of red lead for priming steel. The pigment red lead had a marked hydrolyzing reaction on the oil in which it was ground. The latter contained a very large percentage of lead linoleate, free fatty acid, and glycerin. The iodine number of this oil was lower than that of any other extracted. It is, of course, well known that red lead, on account of its tendency to harden in the package, is seldom put up in mixed form. The dry pigment is generally mixed with oil just before application, from 30 to 35 pounds of pigment to a gallon of oil being the proper consistency for painting.

Zinc oxide and zinc lead had but slight action with the oil, while basic carbonate-white lead showed somewhat greater action,

but not sufficient to be of any detriment. With paints containing mixtures of lead and zinc pigments only slight action was shown. The perfect condition of these paints indicates that any properly-prepared combination pigment paint may be safely stored in cans for long periods without bad effects, provided the oil used is of normal grade.

The most astounding change shown in the tests was that in the iodine values of the oils extracted from all of the paints. It would appear, therefore, that when paints are stored for a considerable period of time and then examined for the iodine value of their oil content a lowering of the iodine value should not constitute cause for rejection or be sufficient evidence to state that the oil was adulterated with oils of lower iodine value. Cognizance of this statement should be given by railroads and purchasing corporations which have adopted specifications for oil paints.

As is well known, linseed oil is a mixture of tri-glycerides of fatty acids. In other words, fatty acids are combined with glycerin in the proportion of three equivalents of acid to one equivalent of glycerin, the latter material acting as a tri-atomic alcohol or base. The fatty acids in linseed oil, among which may be mentioned oleic acid, are of an unsaturated nature, being capable of taking up large quantities of oxygen. The combination of these fatty acids with glycerin may be effected by certain enzymes which exist in the seed of the plant. Moreover, the resolution of such compounds with a consequent breaking away of the acids, from the glycerin, to a free condition, may be accomplished by enzymes which have hydrolyzing properties. This splitting-up reaction may also be effected by several methods of a chemical nature. The hydrolyzing effect of moisture is sometimes of considerable moment and is probably responsible to some degree for the small percentage of free fatty acid which is generally present in all linseed oils. That some oils have higher acid values than others is well known, the acid refined oils being especially high in free acid; treatment with various mineral acids accelerating hydrolysis. The most rapid form of hydrolysis is effected with strong bases such as soda, the ultimate products being water-soluble soda soaps and glycerin. When the hydrolyzing base is a relatively insoluble product and of a metallic nature such as litharge,

the hydrolysis of the oil is slow and only partial, there being formed a water-insoluble lead soap, glycerin, and some free fatty acid.

When hydrolysis has taken place in a paint, considerable thickening is observed. In the tests which are charted above it will be observed that the most extravagant example of hydrolysis was shown by the red lead paint. The oil from this paint showed over 15 per cent. of inorganic lead compounds in the ash. It will also be noticed that the oil had become very acid in nature and had the appearance of a thick jelly, which may be accounted for by the large percentage of glycerin present. Although the red lead paint was very thick, difficult to break up, and too heavy for brushing, it was not really hard. The writer has had occasion, however, to examine several samples of paint recently which were very much harder than the red lead, one, in fact, being so hard that a knife was required to make any impression upon its solidified surface. These paints, moreover, contained pigments of a basic nature, containing a very high percentage of lead and zinc. An examination of the oil in which these paints were ground showed acid values ranging from 8 to 16. That the reaction of the free acid upon the pigments was the real cause of the hardening of the paint was the writer's conclusion. A series of tests were therefore made, in which was included the treatment of paints with small percentages of free oleic acid, one of the most prominent constituents found in oils of a high acid value. There were also included tests in which paints were treated with sulphites, there existing in the paint industry a false belief that lead and zinc pigments are apt to body and harden in oil if they contain even traces of sulphur dioxide or sulphites. Those who have held such a belief should some time examine paints made of sublimed blue lead, a pigment which contains nearly 5 per cent. of metallic sulphites and sulphides. This pigment will remain as a smooth paste in oils for months without any apparent hardening.

Small quantities of dry zinc and lead pigments (basic carbonate-white lead, basic sulphate-white lead, zinc oxide, and zinc lead) were ground in a pure raw linseed oil having a normal acid value of approximately 2.8. After standing for three days, no tendency toward hardening was shown by any of the paints. They were then divided into small portions, and to each type were

added various materials which were under suspicion as having, when used, some contributing effect in the hardening of paint. The following table shows the results of these experiments:

Treatment with 20 per cent. gloss oil (½ rosin, ½ benzine).....	Considerable hardening shown in 24 hours, indicating action between the acid rosin (resinic acids) and the basic pigments.
Treatment with 2 per cent. sodium hyposulphite	No effect noticed in 6 days.
Treatment with 5 per cent. oleic acid.	Hardening occurred in two hours and increased with age. Paint resembled hard putty.

From these results it is apparent that oils of an acid nature are the most active cause of paint hardening. The use in cheaper paints of substitutes for linseed oil, which contain large percentages of rosin, as well as the promiscuous use of acid rosin driers, has been the cause of the hardening of many paints. Linseed oil containing high percentages of acid is, of course, dangerous. It is evident, therefore, that a careful consideration of the vehicle portion of a paint is even more important than the pigment part, and a careful record of the acidity of paint oils should be kept by the grinder.

The author wishes to acknowledge the assistance of Messrs. L. G. Carmick and J. E. Heckel in the analytical determinations.

Nitrates from the Atmosphere in Germany. ANON. (*Oil, Paint and Drug Reporter,* June 24, 1912.)—Nitrate manufactured from the air by the Norwegian and Swedish plants is slowly finding its way to the German market. It is expected that very shortly Norwegian saltpetre will be shipped in large quantities to the centres of consumption. At present the artificial nitrate is selling at 8 to 9 pfennigs more per kilo. than Chile saltpetre, but it is expected the prices will soon be equalized. In 1911 only 493.3 metric tons of sodium nitrate were imported from Norway, as against 730,939 tons received from Chile. Also 473.4 tons of ammonium nitrate were imported from Norway and 139.2 tons from Sweden, and 14,494 tons of calcium nitrate from Norway and 1,033.6 tons from Sweden. New plants for extracting nitrogen from the air are in course of construction not only in Sweden and Norway, but also in Upper Bavaria, in the Tyrol, in Switzerland, and in the valley of the Rhine.

"Electrit" Grinding Wheels. ANON. (*Amer. Mach.*, xxxvii, 1, 24.)—"Electrit" is an abrasive made from pure aluminum oxide by melting it in an electric furnace at a temperature of about 3000° C. (5400° F.). Its specific gravity is less than that of emery and corundum, but its hardness is considerably higher, about 9¼ on the 10 degree hardness scale. The grain of "electrit" is almost amorphous, resistant under pressure and shock, tough and not brittle. "Electrit" grinding wheels are bound ceramically, are proof against moisture and acids, and can be used either for wet or dry grinding.

On the Use of Oxygen Under Pressure to Determine the Total Carbon of Ferro-alloys. P. MAHLER and GOUTAL. (*Mon. Sci.*, ii, 848, 546.)—To obtain complete and perfect combustion the addition of an auxiliary combustible is necessary. Good combustion is attained by adding to the sample two to three times its weight of metallic iron, and lead oxide or copper oxide in amount equal to one-half of the total charge.

"Overshooting" of Lamps in Candle-power. E. J. EDWARDS. (*Elec. World*, lix, 1124.)—There can, theoretically, be no overshooting of temperature when the voltage across the lamp is maintained constant, if the resistance changes are coincident with the changes in temperature. Most cases of overshooting are due to an illusion; for a constant light source seems to flash above its subsequent value, when quickly uncovered before a "dark" adapted eye. From these experiments there is no evidence, in tungsten lamps, that the luminous intensity overshoots its normal value.

Decomposition of Water by Magnesium at Ordinary Temperature. A. W. KNAPP. (*Chem. News*, cv, 253.)—When magnesium is mixed with water no reaction is observed at ordinary temperatures, although the formation of magnesium hydroxide and the liberation of hydrogen is an exothermic reaction. This is explained by saying that the film of hydroxide first formed covers the metal and retards further action. However, if magnesium powder be added to ten times its weight of water, and then palladious chloride equal to one-hundredth part of the weight of the magnesium, a brisk evolution of hydrogen occurs. The magnesium reduces the palladious chloride, forming metallic palladium, which acts catalytically. The small amount of magnesium chloride formed possibly accelerates the reaction by dissolving the hydroxide. The temperature rapidly rises until the water boils and white hydroxide is formed. The palladium, which has accelerated the decomposition of the water, now accelerates its formation, for it is warm, and some of it rising on the bubble-films, which separate the hydrogen from the air, causes the hydrogen to ignite spontaneously.

METROLOGY IN RELATION TO INDUSTRIAL PROGRESS.[1]

BY

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BEFORE the development of modern science, metrology included only the simple weights and measures necessary in commerce and trade. The adoption and preservation of standards of weight and measure, the means of making them accessible to the public, and the enactment and administration of laws preventing the use of incorrect weights and measures have been questions of vital interest to every nation from the beginning of history.

Naturally, the early standards had their origin in some object in Nature, thus recognizing the most vital principle of modern metrology, namely, reproductibility. A history of these standards would prove most interesting. Each community had its own standards, but as trade grew, due largely to the improvement in transportation facilities, it became necessary to unify the standards of communities doing business with each other. During the past century every commercial nation has been compelled to put its standards on a national basis. Even in our own country, as late as 1830, the Secretary of the Treasury was compelled to unify the weights and measures in use in the various customs houses, and as copies of the standards he adopted were furnished the States by direction of Congress, and in turn adopted by them, this act constituted what may be termed the unification of our national standards. Similarly, the time is not far distant when the same force which compelled the various sections of each country to adopt uniform national standards will bring about international uniformity. The countries of the world are closer together to-day, commercially, than were the sections of each country a hundred years ago.

The developments of modern science necessitated the in-

[1] Presented at the stated meeting of the Institute, held Wednesday, May 15, 1912, when Dr. Stratton received the Institute's Elliott Cresson Medal.

troduction of a new factor in metrology, namely, precision, since precise measurements form the foundation of practically all scientific investigation. Commercial standards were not sufficiently reliable or accurate for scientific purposes. The progress of science demanded correctly-defined units and accurate material standards for each physical quantity to be measured, whether in the field of mechanics, heat, light, or electricity. Practically all of these units and standards are based upon the fundamental units of length, mass, and time, and involve measurements of these three fundamental quantities of the utmost refinement in order that the derived units may be determined with the order of accuracy required even in the industries. Hence, much scientific effort has been expended upon the improvement of the units and standards of these fundamental quantities, and the derived units and standards form a never-ending field of scientific research.

But the field of metrology does not end with the fixing of the fundamental standards of length, mass, and time, and the derived units in the field of mechanics, such as force and energy and power, or the deriving and fixing of the various standards used in measurements of heat, light, and electricity, but it includes the determination of a large number of values known as physical constants, such as the mechanical equivalent of heat, the boiling points of liquids, the melting points of solids, thermal and electrical conductivities, the optical and radiation constants, and many others. Accurate values of these constants are as necessary as correctly-defined units or accurate standards of measurement. They enter into practically all scientific work, whether pure or applied, and may be termed "standard values."

Again, the field of metrology is rapidly being extended to include standards of quality. It is often desirable, especially in the industries, to define the quality of a material in terms of its physical and chemical properties, to specify, as it were, its standard of quality. As metrology forms the basis of investigation in the field of natural science, so do the natural sciences constitute the principal factor in industrial progress. When Germany determined to take a leading part in the industrial world, she began by encouraging scientific investigation and instruction. She had reached the front rank in the scientific world long before reaching that same position in the industrial field, and her phe-

nomenal industrial progress can be attributed to the application of scientific methods and principles more than to all other factors combined.

Metrology has a direct bearing of great importance upon industrial progress, as shown in the interchangeable method of manufacturing, a method depending upon the accurate measurement of length, the accurate measurement of temperature in the steel, glass, ceramic, and other industries where it was formerly estimated, and no field of industry owes more to metrology than that of applied electricity. These are but a few of the vast number of cases that might be recited, but metrology is probably far more important to industrial progress, indirectly through the channels of applied science.

This country has enjoyed a remarkable period of industrial prosperity, due to the enormous home consumption of our manufactured products by a rapidly-increasing population of a new and growing country, and the retention of the home market for our own use. Nevertheless, competition as to quality is growing very keen, and our manufacturers are becoming aware of the great importance of scientific investigation, the leading industries are rapidly establishing research laboratories in which units and standards of measurements are the principal means of attacking the difficult problems they are called upon to solve. These laboratories are quite as exacting in their requirements as to accuracy as the laboratories of scientific institutions. The usefulness and efficiency of such laboratories are increased manyfold by the access to accurate, reliable standards and methods of measurement. There is scarcely a business transaction, an exchange of commodities, an article manufactured, or a structure erected that does not refer in some way, either directly or indirectly, to standards of measurement.

Every progressive country has recognized early in its history that the fixing of standards is a governmental function and has early made provision for the maintenance and use of the standards used in trade. Later, these countries, recognizing the new and broader field of metrology and its vital relation to industrial development, have established national institutions equipped for scientific investigations in all branches of metrology. The first of these was the Physikalisch-Technische Reichsanstalt, established by Germany in 1884, dealing with the newer branches

of metrology, including light, heat, electricity, and the determination of important physical constants in these same fields of science. This institution was, in addition to the laboratory of the Normal Eichungs-Kommission, having to do only with the ordinary standards of trade, and its phenomenal influence upon the industrial development of Germany is too well known to comment upon at length at this time. Later there was established in Germany still another institution, the Material Prüfungsamt, dealing with the subject of metrology in its newest and broadest sense, namely, the determination of the properties of the more important materials of construction and other industrial products. While this latest standardizing institution is essentially supported by the Prussian Government, its influence is felt throughout the Empire.

In 1898, Great Britain established the National Physical Laboratory near London, again an institution made necessary by the ever-widening field of metrology. This institution is growing by leaps and bounds and is already an important factor in the industrial development of that country. It has taken a place in the front rank of scientific laboratories and is doing a great work. In our own country the founders of the Government gave to Congress the responsibility of fixing the standard of weights and measures by constitutional provision. In framing this paragraph of the Constitution, they no doubt had in mind as examples the standards then recognized as necessary; but the principle involved and established applies equally well to the standards of electricity, heat, and all others that have become necessary, or may become necessary in the future, to commerce, trade, and industry.

As in other countries, the weights and measures of trade were first provided for, but, curiously, never by direct legislation, except in the case of the Troy pound of the Mint. The Superintendent of the Coast Survey, the first scientific bureau of the Government, purchased a standard of length from a London instrument-maker, since such a standard was the first thing necessary in making the coast and geodetic surveys of the country. The Secretary of the Treasury secured a copy of the British Troy pound for use in the coinage of money and from which the avoirdupois pound was derived, the grain of each being the same. He further adopted the Winchester bushel

and the wine gallon, which had been in use in the Colonies. In 1836, the British standard of length was destroyed by fire. In reconstructing a new standard from the best copies of the old one, several copies were made, one of which was presented to this country in 1856.

The metric system of weights was legalized by Congress in 1866. In 1872, a conference was held in Paris by the representatives of thirty countries, the United States being represented, and provision was made for the construction of new metric standards of length and mass. They were made of an alloy of platinum and iridium, the most durable materials known, and by the most accurate methods known to science at the time. The copies sent to this country in 1890 were adopted by the Secretary of the Treasury as our metric standards. In 1893, the relations between the yard and the meter and the avoirdupois pound and kilogram were fixed by that official, based, of course, upon an accurate comparison between the standards of the two systems. From this time the meter and the kilogram became the fundamental standards for both systems, thus giving to the common system the advantages of the metric, so far as permanency and accuracy are concerned. One should not confuse the terms "unit" and "standard"; if the relation between the yard and meter—both units—is known, then it is only necessary to measure off on a subdivided meter that portion which has been defined as equivalent to the yard. In a similar manner, the pound is determined from the standard kilogram.

Briefly, this is the history of our fundamental standards, both for industrial and scientific purposes. A small office of weights and measures, with four or five employees, had grown up in the Coast Survey, a bureau of the Treasury Department, in which the standards of the public were compared, to a limited extent, with those of the Government, the functions of the office being exercised mainly for Government uses. This office was superseded in 1901 by the Bureau of Standards, a new bureau in the Treasury Department, with functions sufficiently broad to cover the great variety of standards now required by the industries, the value of physical constants, and such properties of materials as are needed in standardizing them. This bureau was transferred to the Department of Commerce and Labor at the creation of that department. It might

equally well have been termed the National Bureau of Metrology. Its employees, scarcely more than a dozen at the start, now number approximately 300; it is provided with three large, well-equipped laboratories, with another in process of construction. Fortunately, the various metrological functions were here combined in one institution instead of several, as in those countries where they have been taken up one after another, thus ensuring a co-operation between the various branches of metrology and which cannot be economically or efficiently separated one from another.

It is not my purpose to describe in detail the work of the Bureau of Standards, but a few examples of the work now in progress will perhaps illustrate better than by any other method the relation of metrology to the industries. Those familiar with manufacturing need scarcely be told the importance of length, mass, volume, and density measurements in all branches of industry. The requests for the comparison of length standards come from the makers of all kinds of length-measuring instruments, from the makers of machinery and tools. Practically all of the measuring tools of every sort used by workmen in construction are made from standards that have been compared with those of the bureau. The bureau is never without the standards of the makers of weights; the standard weights of manufacturing concerns, railroad companies, or the precision weights used in industrial laboratories, all awaiting comparison with the Government standards. Oil companies have their standards of capacity verified. Gas meters are referred to standards of capacity—as well as the glass measuring apparatus used in industrial and scientific laboratories. Hydrometers, or instruments for measuring the densities of liquids, are used in great quantities and variety; tables of densities of various kinds must be prepared for use in connection with them. The internal revenue on alcoholic liquors, amounting to many millions of dollars annually, is collected in accordance with the readings of these instruments, all of which are tested at the bureau. These are but a few of the instances involving standards of length, mass, capacity, and density, to which one of the largest sections of the bureau is devoted.

The electrical industries are as exacting as to their requirements of standards as scientific laboratories. This industry has,

perhaps, more than any other, adopted scientific methods and precision measurements. The standards of the makers of electrical measuring instruments, as well as those of the producers and users of electrical energy, must be compared with a common standard, and that standard (or standards, as there are several of them) must be derived from the fundamental standards of length, mass, and time—an exceedingly difficult operation. The Electrical Division of the bureau was called upon recently by the electrical industries for a determination of the conductivity of copper—a physical constant of great importance to that industry—and it is frequently called upon to determine the electrical properties of materials. It is undertaking an investigation of the electrolysis effects of stray currents upon underground pipes or other metal construction with a view of determining some of the data necessary in standardizing electrical construction and the prevention of electrolysis, an excellent illustration of the many investigations in progress at the bureau for the determination of the properties of materials under specific conditions, in order that they may be more properly used.

In addition to the vast number of temperature measurements made at ordinary ranges in industrial processes, many of these processes depend for their success upon measurements of high temperature. This is especially true of the steel, glass, porcelain, and similar industries. No branch of metrology presents more varied problems or is more closely connected with industrial progress. The calorific values of gases and other substances are being determined. Only a few days ago the refrigerating industries requested the bureau to determine the heat constants of ammonia and brine, the heat-insulating properties of materials, and other constants needed by that important industry.

Many of the constants and values given in tables of reference are out of date and need to be redetermined with all the precision possible in modern metrology.

One scarcely thinks of optical measurements in connection with metrology or industrial progress, and yet optical measurements are an important factor in both. The applications of spectrum analysis are many. The duty upon imported sugars, amounting to seventy or eighty millions of dollars a year, is

collected according to the amount of pure sugar they contain, as determined by measurements involving the principles of polarized light, and every one is familiar with the relation of photometry to the gas and electric industries. Standards of color and color-measuring instruments are desired that are applicable for the measurement of the color of textiles, paper, pottery, and butter, and many other materials. In fact, an instrument for measuring color has been recently developed at the bureau, and the substances mentioned are those that were being measured but a few days ago during my visit to this particular laboratory. Investigations are in progress for the purpose of determining the data necessary in defining the optical properties of the various lens combinations, such as field glasses, photographic lenses, telescopic objectives and others, and also the means of specifying and measuring these properties.

Metrology, in the broad sense, includes not only the various fields of physics, but chemistry as well. Scarcely a problem is taken up, either in connection with standards of measurement, constants, or the properties of materials, that does not involve chemical analysis. Standard irons, steels, ores, and so forth, of known compositions are required by the metallurgical industries; the chemical industries are demanding standards of purity in reagents.

Standards of quality have to do with the manufactured product rather than the process of manufacture, and they have an exceedingly important bearing upon industrial products. The newest and largest section of the Bureau of Standards is that devoted to the investigation and determination of the properties of the more important structural and engineering materials in order that they may be correctly specified and most efficiently used. The bureau tests large quantities of such materials purchased by the Government. In doing this, it is brought in contact with faulty definitions, imperfect specifications, and, in many cases, the entire absence of standards of quality or suitable methods of testing. This work is of great financial value to the Government, but it is insignificant as compared with that of the knowledge that is gained by doing it and which can be given to the public.

The bureau endeavors to serve as a clearing-house for knowledge pertaining to metrology. Scarcely a day passes that it is

not visited by several representatives of various industries seeking information as to standards, methods of measurement, or the properties of materials; every mail brings scores of such inquiries from every section of the country and from all branches of industry. The bureau serves as referee in many cases of dispute when questions of standards are involved, and it is frequently instrumental in bringing about an agreement between manufacturers and users as to standard specifications.

There is a decided and rapidly-growing tendency on the part of the public to purchase structural and other materials according to properly-framed specifications, and to ascertain, by suitable tests, whether or not the articles purchased comply with the specifications. Hence, the bureau encourages the establishment of local testing laboratories, especially in the large cities, by furnishing them with standards, assisting them in the preparation of specifications, and giving them the results of much valuable experience gained in doing similar work for the Government. The time is not far distant when every large city will have its testing plant, dealing not only with the measurements involved in the public utilities, but testing all materials purchased for use in public work.

Finally, I would call attention to the efforts of the bureau toward promoting international agreement as to the fundamental questions involved in metrology. Largely through its influence a very close co-operation has sprung up between the various national bureaus. They are continually exchanging standards and comparing methods. The necessity for international agreement in such matters is becoming daily more and more apparent. The scientific world employs only international standards—why should not the industrial and commercial world enjoy the same privilege?

In conclusion, I would state that if there is one thing above all others for which the activities of our Government during the past two or three decades will be marked, it is its original work along scientific lines, and I venture to state that this work is just in its infancy. The expenditures of the Agricultural Department, great as they have been, have produced results of untold value to the agricultural interests of the country, and it is hoped that the Government may take a similar position in reference to other branches of our industrial interests.

Utilization of Asphaltum Residues. ANON. (*Oil, Paint and Drug Reporter,* June 24, 1912.)—It is shown by the Geological Survey's publication, "Mineral Resources," that the chief feature of the asphaltum industry in 1911 is the great extension of the use of residues from the asphaltic varieties of petroleum as binders on the surfaces of macadam roads in order to prevent deterioration. The asphaltum used for this purpose increased from 159,424 tons in 1910 to 234,951 tons in 1911. The importation of soft asphaltum from Venezuela, which is admirably suited for this purpose, is increasing. A by-product of the oil industry is fast supplying the demands for asphaltum in the United States. The petroleum from California and Texas has furnished large supplies of asphaltic residue, which, when treated with air, becomes sticky and even elastic to a certain extent. Elastic material for roofing and substitutes for rubber in automobile tires have been obtained from asphaltic residues by the blowing process or by treating with sulphur. This sulphurization of asphaltum has been applied with good effect to elaterite and similar hard asphaltums from eastern Utah.

The Mass of the Particles Which Emit the Two Spectra of Hydrogen. C. FABRY and H. BUISSON. (*Mon. Sci.*, ii, 848, 551.)—Hydrogen gives two very different spectra: the first composed of rays whose distribution obeys Balmer's law; the second, in which the rays are very numerous and are distributed irregularly. An attempt was made to ascertain if the one or the other of these spectra was not emitted by a complex atomic aggregation, such as the molecule. The study of the size of the rays enables us to determine the mass of the particles which emit the different radiations, referred to the ordinary system of atomic masses. Now the formulas referred to enable one to deduce from the number of the limiting order of the interferences given by the rays of the second spectrum the mass of the particles which emit these rays; this mass is found to be very appreciably equal to the atomic mass of hydrogen. The rays of the second spectrum then are emitted by corpuscles identical with the atom, or which differ but very little from the atom, and not from a combination of several atoms. It is concluded, therefore, that the rays of hydrogen, those of the secondary spectrum as well as those of the spectrum in series, are produced by particles of the same mass as the hydrogen atom.

Preparation and Heat of Formation of Magnesium Nitride. C. MATIGNON. (*Mon. Sci.*, ii, 848, 546.)—The best method of producing magnesium nitride is to pass a current of absolutely dry ammonia gas over finely divided magnesium heated in a nickel or magnesium boat. The heat of formation of the nitride from its elements is 119.7 calories, according to the equation $3Mg + N_2 = Mg_3N_2(\text{solid}) + 119.7$ calories. Hence nitrogen has a high affinity for magnesium.

WATERWAY IMPROVEMENTS.[1]

BY

LEWIS M. HAUPT, C.E.

By virtue of the increased tonnage and draught of vessels, the constant deterioration of river channels and harbor bars has led to the expenditure of enormous sums of money in efforts to maintain the world's maritime traffic through such channels.

Attempts have been made to solve this complex problem of deterioration by the use of jetties in pairs, aided by dredging, and great progress has been made in the efficiency of hydraulic dredges. Mechanical appliances do not modify, however, the forces which mould the beds of the channels in plastic material and can never serve to automatically maintain the depths they tentatively secure.

For the purpose of ensuring greater safety, speed, and economy in the maritime interchange of trade, the expenditures by all nations will aggregate more than $100,000,000 annually. Yet the possibility of preventing such expenditures by utilizing the energy of the maritime forces themselves, instead of endeavoring to combat those forces, does not seem to have been realized until within the last few years, when the utility of such a system has been fully demonstrated, even under exceptionally adverse conditions.

Prior to the improvement of the South Pass in 1879 by two curved jetties, the ruling depths of the Gulf of Mexico at the inlets were from 3 to 12 feet, and large sums of money had been expended in efforts to obtain deeper water, but with little effect. At Galveston, however, after a lapse of some thirty years and an expenditure of over $10,000,000, a tortuous channel of more than 30 feet has been provided, though the bar has advanced over three miles and constant dredging is required to maintain the depths.

At Liverpool, England, it was estimated that the removal of 9,000,000 cubic yards of material would suffice to secure a 30-foot channel to the port.

[1] Abstract of paper presented at the meeting of the Mechanical and Engineering Section held Thursday, February 8, 1912.

Since 1890, however, more than 121,000,000 tons have been dredged and the depth resulting from it was, in 1908, 28 feet.

In sedimentary streams, jetties merely serve to temporarily extend the flanks across the bars and to deposit the silt beyond, in the path of navigation. Thus, the delta of the Mississippi deposits 440,000,000 cubic yards annually, of which more than 102,000,000 cubic yards traverse the Southwest Pass, which is being improved by jetties and dredging. The bar is now over half a mile beyond the ends of the jetties.

Problems such as the above require for their solution a consideration of all the forces and their results, as recorded by the physical forms which they create.

Before the Civil War it was the policy of the Government to aid the States and localities in the conduct of public works on river and harbor improvements. The total expenditures made for that purpose from the National Treasury were less than $15,000,000. Since the Government assumed control of the rivers and harbors, however, it has expended to date about $600,000,000 in efforts to meet the demand for deeper channels. The average yearly appropriations made for this purpose during the last decade are less than $25,000,000, and the commercial interests are demanding double this amount to meet the requirements of trade. The Administration is committed to the policy of completing the existing approved projects, aggregating more than $300,000,000, before any new obligations are assumed.

In making analyses of the several methods of improvements adopted, due consideration must be given to the local physical conditions of tides, currents, winds, waves, and fluvial waters at the mouths of sediment-bearing streams. The littoral drifts, character of material, and rates of movements of purely tidal inlets must also be considered.

The official reports of the Government Engineers, the United States Coast Survey, and other publications furnish data on the methods adopted in the following cases of some of the principal harbor and river entrances along the alluvial seaboard of the United States:

THE DELAWARE RIVER.

For a generation efforts have been made to deepen this river, first to 26, then to 30, and now to 35 feet.

The present project for a 35-foot channel contemplates the use of dikes. The estimated cost of the project is $10,920,000, with $300,000 for its maintenance. The time required to complete it is six years.

Since 1836 there has been expended a total of $10,876,002.18, and the depth as reported is about 28 feet at mean low water. The 26-foot channel project was inaugurated in 1885, and in 1899 was merged before its completion into the 30-foot project, which is now embodied in the present 35-foot plan.

Since 1870 there have been many changes of officers in charge of these improvements and of Boards of Engineers reporting on modifications. The plans have been changed from the prohibition of depositing dredged material in the bed of the stream to the construction of dikes, with a return to dumping behind islands or in artificial enclosures, and again to partial dams connecting natural islands with the adjacent shore. The effect has been to throttle the tides and in some instances, where the water is excessively deep, to make it still deeper, with a consequent shallowing of the resultant shoals. The dikes have been restrained because of encroachment on the riparian rights of the adjacent States, and are now located so as not to act as training walls to maintain the channels from which they are too remote or placed nearly at right angles, greatly reducing the normal cross-section.

THE CHARLESTON ENTRANCE.

In 1878 it was proposed to secure a 21-foot channel over the outer bar of this entrance by two low-tide and submerged jetties at a cost of $3,000,000.

This was modified ten years later, when it was projected to raise the jetties and extend their length at a cost of $4,380,500.

In 1899 another modification was made to procure a 26-foot channel by building larger dredges. In 1910 again, with still more powerful dredges, a 28-foot channel was aimed at, this to cost $371,616.88 additional, with $40,000 for maintenance.

The total cost to June 30, 1911, was $4,783,265, and a good 26-foot channel was reported. Tide, 5.2 feet. The improvement has, however, had no effect on freight rates, although the insurance has been slightly reduced. A project for further enlargement is pending. The three dredges, when working, during the year removed 1,212,722 cubic yards, bin measure, but the solid

removed was apparently much less and the cut is filling from the north side. The average cost per yard was 10.89 cents.

THE ST. JOHN'S BAR.

To obtain a navigable channel of 15 feet from Jacksonville, Fla., to the sea, a distance of 27.5 miles, it was estimated, in 1879, that two convergent low-tide jetties, supplemented by dredging, would be required and that the cost would exceed $1,000,000. The project, when carried out, resulted in a 13-foot channel at a cost of $1,417,000.

Modifications were made in 1896 and again in 1903 to secure a 24-foot channel, by raising the jetties and by dredging, at a cost of $2,176,750. The work was nearly completed and $3,017,890 had been expended, when a new project was adopted in 1910 for a 30-foot channel, at an estimated cost of $2,852,000.

About 4 per cent. of this latter modification is completed, and the maximum available draft is 22½ feet.

CUMBERLAND SOUND, GEORGIA.

The bar in this sound carried originally from 11 to 12.5 feet of water at low tide and was very unstable, drifting through a range of 1½ miles. A proposal was consequently made in 1879 to improve it by two low jetties, 3,900 feet apart, which were expected to give a 19-foot channel by dredging at a cost of $2,071,023. There was expended under this project $932,500.

In 1891 a Board of Engineers recommended the raising of the south jetty to high water throughout, in case the low jetties failed to secure sufficient depths. The plan was modified by Captain Carter in 1895 for two rip-rap jetties extending to 30 feet of water and estimated to cost $2,350,000. Captain Carter's plan was approved.

The reported depth in 1897 was but 13 feet, and the channel crossed the south jetty about 7,000 feet from its initial end.

To enable vessels to enter the port of Fernandina, a portion of the south jetty was removed and an emergency appropriation of $500,000 was passed by Congress to relieve the port from closure.

On the building up of the outer end of the north jetty a channel was soon scoured out under its lee by the natural action

of the currents, and this has since been deepened by dredging, so that the controlling depths last year were 24.5 feet.

In this connection it should be recorded that on October 8, 1890, or about a year after the receipt by him of the "Physical Phenomena of Harbor Entrances," Captain Carter recommended a change of plan in the location of the jetties and the abandonment of the south jetty, with the substitution of a concave outer jetty on the north side of the channel. He estimated that his plan would save $1,096,417. Report of 1901, page 1600, gives the opinion of the Board of Engineers on this plan, however, which is as follows:

"It does not think that a single jetty on the north side of the channel curving gently to the south would secure the deep water needed, but that two jetties are necessary. . . . The idea that a curved channel conforms to the natural requirements of the site and opposes the action of the natural forces less than any other is believed to be fallacious."

THE MOUTH OF THE MISSISSIPPI.

In 1803 Louisiana was purchased by the United States, to secure control of the outlet to the Gulf, and fifty years later the Government began to rake and dredge the bars in efforts to obtain a channel of 18 feet instead of from 9 to 12. Three hundred and thirty thousand dollars was appropriated in 1856 for the purpose of building jetties at the Southwest Pass and stirring up the bottom, but the channel was only maintained so long as the stirring was continued, which was only for one year. By 1870 a powerful dredge was built and used to stir up the bottom, throwing the material into the current, but it did not succeed in maintaining a channel, so that in 1871 the proposition was made to dig a canal at Fort St. Philip, to cost $10,273,000, and secure a passage 25 feet deep by locks. This was met by a proposal by James B. Eads to construct two jetties and obtain 28 feet by dredging at a cost of $10,000,000. Captain Eads's plan was submitted in 1874. In 1875 a Board of United States Engineers reported a project for two straight jetties, to be supplemented by stirring or dredging, to secure a 25-foot channel, and to cost, if at the South Pass, $7,942,110, and if at the Southwest Pass, $16,053,124. The Chief of Engineers declined to approve this

project, and Captain Eads then proposed to open a 30-foot channel at Southwest Pass for $8,000,000 and to maintain it for 20 years at a cost of $150,000. Congress gave him the South Pass work in March, 1875, and in July, 1879, he had secured a channel 200 feet wide at the 26-foot depth, with a maximum of 30 feet, under his contract for $5,250,000.

Thus, 76 years after the purchase, the river was opened for deep-draught vessels by a channel supposed to be adequate for all time. It was not long, however, before the commerce demanded a greater channel, and in January, 1899, a new Board estimated on two parallel straight jetties to open the Southwest Pass at a cost of $13,000,000 for construction and $390,000 annually for maintenance.

At the request of a member of the River and Harbor Committee, the writer prepared a project for a 35-foot channel and offered to open the pass at a cost of $6,000,000, with $100,000 for maintenance. The plan was referred to a Board of Engineers, which modified it, suggesting what was known as the "bottle-shaped" jetties, to be accompanied by dredging, at the low cost of 4 cents per yard; total cost, $6,000,000. As these two jetties, at distances varying from 3,000 to 7,000 feet apart, constituted a trap for sediment, the project was again modified, though not improved, and a contract made for its construction in 1903, after the writer had demonstrated the probable results of the modifications.

The following extracts from the last report of the Chief of Engineers will indicate the present conditions of the work and results:

Southwest Pass was obstructed by a bar having 9 feet depth, and in the pass proper they reached to from 26 to 83 feet, mean low water. The existing project was adopted by the act of June 13, 1902, for a 35-foot depth and 1,000 feet in width, by dredging, two jetties to maintain the channel, the closure of all minor channels and removal of obstructions, sills, etc. The act also authorized the Secretary of War to modify the plans of 1900. Construction of jetties began December 31, 1903, and they were completed January 5, 1908, at a cost of $2,627,087.60. Total lengths about 37,000 feet. Cost, about $71.54 per foot. The dredge "Barnard," built at a cost of $240,000, reached

New Orleans September 3, 1904, and began work in the pass, April 21, 1905. Since that date dredging has been continued with the "Barnard," "Benyaurd," "St. Johns," "Sumter," and "Atlantic," and 8,131,256 cubic yards were removed up to June 30, 1911. Dredging was also done under contract in 1907 and 1908, when 3,574,318 yards were taken out and $466,035.31 paid the contractor. Sills were placed, outlets closed, buildings erected, machinery bought, and an additional dredge ordered, all of which have caused an expenditure of $5,620,276.88. Operations during the last fiscal year have resulted in the removal of 3,163,214 cubic yards by dredging.

On April 13, 1911, a contract was made for extending the east jetty 3,000 feet and the west jetty 3,750 feet and the building of two spur dikes. Ten spur dikes were built in connection with the jetties aggregating 7,240 feet in length. The available depth of channel is 31 feet at mean low water. The available depth in the South Pass at the same date was 29 feet.

"Any improvements in a stream like the Mississippi must be effected, both in time of execution and cost of operation, by conditions beyond human control."

Deductions.—The total prism of excavation since April, 1905, is 14,858,788 cubic yards, giving an average yearly removal of 2,409,528 cubic yards at an average cost of 6.33 cents per yard, instead of 4, as estimated, or nearly 60 per cent. higher. The estimated discharge of silt through this pass is 102,000,000 cubic yards, so that the dredges have handled only about 2 per cent. of the total, and, the outlets being closed, the residue must be discharged through the jetties, hence the rapid advance of over 3,000 feet in 7½ years since this project was begun. The normal rate was a half mile each decade. The ruling dimensions of the channel on June 30 were, depth 31 and width 360 feet. The spurs built during the year have aided in the deepening and indicate that the jetties are too far apart, and the groins are filling with sediment, as they should. It is manifest, therefore, that the jetties have hastened the advance of the bar and increased the deposits beyond them, while the channel is not self-maintaining. The east jetty has settled 1.6 feet and the west jetty 1.8 feet since being capped. The total appropriation has been $6,925,643.89, of which $5,620,276.72 is expended.

TAMPICO HARBOR AT MOUTH OF PANUCO RIVER, MEXICO.

(Extract from "Shipping Illustrated" for February 18, 1911.)

"The Mexican Government has made an appropriation of $10,000,000 to extend the jetties at the mouth of the Panuco River at Tampico, by which the present deep-water harbor is formed, farther into the sea for a distance of 700 feet and for dredging the bar at the mouth of the river. The stone breakwaters will be concreted on the sides and top and a walk constructed thereon."

The bar at the mouth of the Panuco River was about 4,400 feet off shore, and its depths varied from 5 to 12 feet with the seasons. It was improved by the construction of two straight, parallel, rip-rap jetties, of which the southerly one was 6,800 and the northerly one 6,500 feet long and 1,000 feet apart, capped with random stones weighing several tons, roughly placed from trestles, and afterwards maintained by derrick barges. The work was begun in March, 1890, and completed about the end of 1892, at a cost of $2,221,000 United States currency.

The fluvial discharge from the high plateaus is rapid and at its maximum reaches 215,000 cubic feet per second, having a velocity through the jettied channel of 7 feet per second and a slope of 10 inches per mile. The cross-section of the stream is 19,460 square feet. In heavy floods the ratio of sediment to water is 1 to 400, in ordinary stages it is 1 to 1,300, in bulk. There is a diurnal tide of 15 inches and a littoral drift to the southward, especially during the winter season. The flood of the summer of 1893 scoured out some 1,202,000 cubic yards, and the total removed amounted to about 4,000,000 cubic yards, resulting in a depth of 26.5 feet at mean low water, which was fairly well maintained by dredging at intervals.

On June 24 it was further reported as from the British Consul: "The condition of the harbor at Tampico leaves much to be desired in the way of dredging. The dredge is too small to keep the channel clear. The depth on the bar does not permit vessels drawing over 22½ feet to enter. The Government contemplates extending the jetties and their reconstruction, hoping to secure 30 feet."

The Tampico jetties, as well as those at the South Pass, were under the immediate construction of the world-renowned mari-

time engineer, Mr. Elmer L. Corthell, and are among the most satisfactory works of their class, both as to design and results, yet it would seem that even at the mouths of large streams bearing sediment they have their limitations and are not automatic and self-maintaining.

NOTES ON THE COLUMBIA BAR, OREGON.

(Data Compiled from Report of Chief of Engineers, 1911.)

In 1884 the first project was made for a half-tide jetty, 4½ miles long, on the south side, to be built of rubble stone deposited from a trestle. Temporary result, 31 feet, during readjustment of equilibrium. Cost, when raised to high tide with four groins added, was $1,968,753. Completed in 1895, followed by rapid shoaling, to arrest which the project was modified in 1903 by the proposed extension of the south jetty 2½ miles, the building of a north jetty, and by dredging. In 1901 the depths had shoaled to 21 feet and the channel had drifted some two miles to the northwest.

The estimated cost to secure 40 feet was $3,715,000. This project was again revised to raise the jetty to mid-tide level, in 1909, at a cost of $3,529,300, and to make it 25 feet wide at that level. In some places it is in 39-foot depths, thus "requiring an enormous increase in the amount of rock." Between September 20, 1910, and June 30, 1911, the dredge worked on the bar 62 days, removing 212,080 cubic yards of material. Project is 85 per cent. completed.

The survey of June shows the channel to have shifted about 2,500 feet to the northwest and that the depths vary from 25 to 27½ feet, an increase of 1 foot over last year. The mean tide is about 7.4 feet.

"The life of the trestle is very uncertain. . . . It is believed that the contraction of the entrance by the north jetty may be followed by scouring along the north side of the south jetty, and that for the maintenance of the south jetty two more groins should be provided, each about 500 feet long."

The total appropriations since June 13, 1902, aggregate $7,901,852.24.

From the above it appears that the actual gain in depth by jetty and dredging is about 5 feet, in some ten years, giving an average cost per foot of $1,580,370, and that the crest of the bar

is still two miles beyond the outer end of the extended jetty, while the channel is not fixed in position, but is still drifting rapidly northward, and the cut dredged has less depth than before it was begun. "The outer 24-foot contour has advanced some 3,000 feet since 1902, and the depths of 50 feet in that year had shoaled to 24 feet by 1909. On the southerly side of the jetty the 24-foot curve had advanced about 4,000 feet within two years, or about twice the length of the jetty extension in the same time, and large deposits had been made in the throat of the entrance between the jetty and Peacock Spit."

The proposed north jetty will merely arrest the northwardly moving littoral drift and cause more rapid advance of the bar, as has frequently happened elsewhere.

THE REACTION BREAKWATER.

As early as 1869, the writer, while stationed in Texas as United States engineer officer in charge of the district, began his investigations on these harbor questions, and after extended researches on snow-drifts, sand-dunes, and river currents, and also repeated surveys of shifting inlets, a system of works was evolved whereby a portion of a single, curved, resisting medium was so designed as to protect the bar-crossing from the resultant littoral drift, yet at the same time admitting the full tidal prism to the interior compartments, confining the effluent tides to a contracted path, and also causing a *reaction* by a constant change of direction, accompanied by scour and lateral transportation, and with no bar advance nor material interference with the prevailing littoral movements. By this means of connecting the deep water within and beyond the bar by a visible aid to navigation, under the lee of which there could be no shoaling because of the activities of the effluent waters, the current automatically constructed its own channel.

At Aransas Pass, Tex., the plan was tested on a practical scale by putting into position in twelve years instead of *one* a breakwater guaranteed to create a 20-foot channel across a bar of from 6 to 8 feet in depth.[2] The automatic channel has been secured by the feeble diurnal tide of 14 inches, at a cost of *less than one-fourth* of the amount estimated for the two-jetty channel. A ter-

[2] JOURNAL FRANKLIN INSTITUTE, February, 1908.

minal harbor is now being constructed with modern facilities for a commercial emporium on the Gulf for more than a million square miles of tributary territory.

The pass now has 23 feet of water 300 feet in width in the Gulf.[3] This is three feet more than the Government proposed to secure by two jetties with dredging at an estimated cost of $2,052,542 for dredging alone, thus effecting a saving of over $1,616,078.

In other cases than the above, these methods are now being applied whereby bar and river channels are maintained automatically by the action of natural forces, and without recourse to constant dredging and stirring and other mechanical methods of removal.

The Conservation of Vital Resources.—To endeavor to arouse a national sentiment for the conservation of vital resources two Congresses have this year been organized and will be held this month. The Fourth National Conservation Congress will take place at Indianapolis, Ind., from October 1 to 4, inclusive, and the above subject has been taken for its main theme. Coincidently, the First Coöperative Safety Congress will meet at Milwaukee, Wis., from September 30 to October 5. This latter is under the auspices of the Association of Iron and Steel Electrical Engineers, which will hold parallel and joint sessions with it.

Density of Solid Substances. J. JOHNSTON and L. H. ADAMS. (*Amer. Chem. Soc. Journ.*, xxxiv, 563.)—A new form of pyknometer has been designed capable of determining the density of solids to within 0.02 per cent. Powdering a homogeneous crystalline substance free from unsoundness does not affect its density. Very high hydrostatic pressure has no permanent effect on the density of homogeneous crystalline materials. On metals, pressure first increases the density by closing the pores or interstices, after which the density decreases, sometimes below the original value. Subsequent annealing increases the density. Contrary to Spring's observations, bismuth decreases in density after deformation. A comparison of the data obtained with the observations of Beilby indicates that the amorphous phase is similar to an undercooled melt. The result of deformation, therefore, should be to produce a change of density in the same direction as that produced on fusion, and this is the case with all metals except bismuth.

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[3] *Shipping Illustrated*, February 3, 1912. See *Cassier's Magazine*, April, 1909, for paper on "Barriers to International Trade."

Abuses of the United States Patent System. L. H. BAEKELAND. (*J. Ind. Eng. Chem.*, iv, 333.)—The difficulty and expense of enforcing patent rights in the United States courts are very great, and a patent is often worthless to a man of limited resources. Successful litigants seldom recover damages for infringement, or not sufficient to cover legal expenses. The wealthy corporations are able to bluff their weaker competitors or to crush them by prolonged litigation, and the money so spent is ultimately paid by the consumer. Separate final decisions are given by each of the nine Circuit Courts of Appeal, and these decisions are not always in harmony. Evidence is not taken by testimony in open court, and in one case 36 large octavo volumes of printed testimony, containing much repetition and irrelevant matter, were submitted. The proceedings in "interference" cases involving the respective rights of inventors applying concurrently may be prolonged for years. The reforms suggested are similar to those proposed by W. F. Rogers.

Mercury Production of the United States in 1911. ANON. (*Oil, Paint and Drug Reporter*, June 24, 1912.)—The production of mercury in 1911 in the United States was the greatest since 1907, the total output being 21,256 flasks of 75 pounds each, valued at $927,989, against a production of 20,601 flasks, valued at $958,153, in 1910. California was the greatest producer in 1911, with 18,860 flasks, valued at $867,749, and the remainder came from Nevada and Texas. The annual domestic consumption appears to be from 18,000 to 21,000 flasks, or about equal to the domestic production. The decrease of domestic stocks, and higher prices in 1911, caused the heaviest importation of mercury in many years. On the other hand, exports of mercury decreased from 1,923 flasks in 1910 to 291 flasks in 1911.

Gold, Silver, and Iodine in Sea Water. H. S. BLACKMORE. (*Cass. Mag.*, xli, 3.)—The value of the gold in a cubic mile of sea water is $93,184,000; that of the silver is $8,644,600, and that of the iodine, $62,003,200. It is suggested that if a suitable precipitant for these elements could be found it would be possible, by means of huge tanks automatically filled at high water and emptied at low tide, to realize large sums by their recovery. The gold and silver seem to be held in solution by the iodates and iodides of sodium, potassium, calcium, and magnesium, particularly the iodates, which tend to precipitate the gold and silver when reduced to iodides. This precipitation is gradually going on in creeks and inlets where reducing agents, such as occur in sewage, are present; the mud in such inlets contains considerable gold.

THE ELECTRO-PNEUMATIC BRAKE SYSTEM FOR STEAM ROAD SERVICE.[1]

BY

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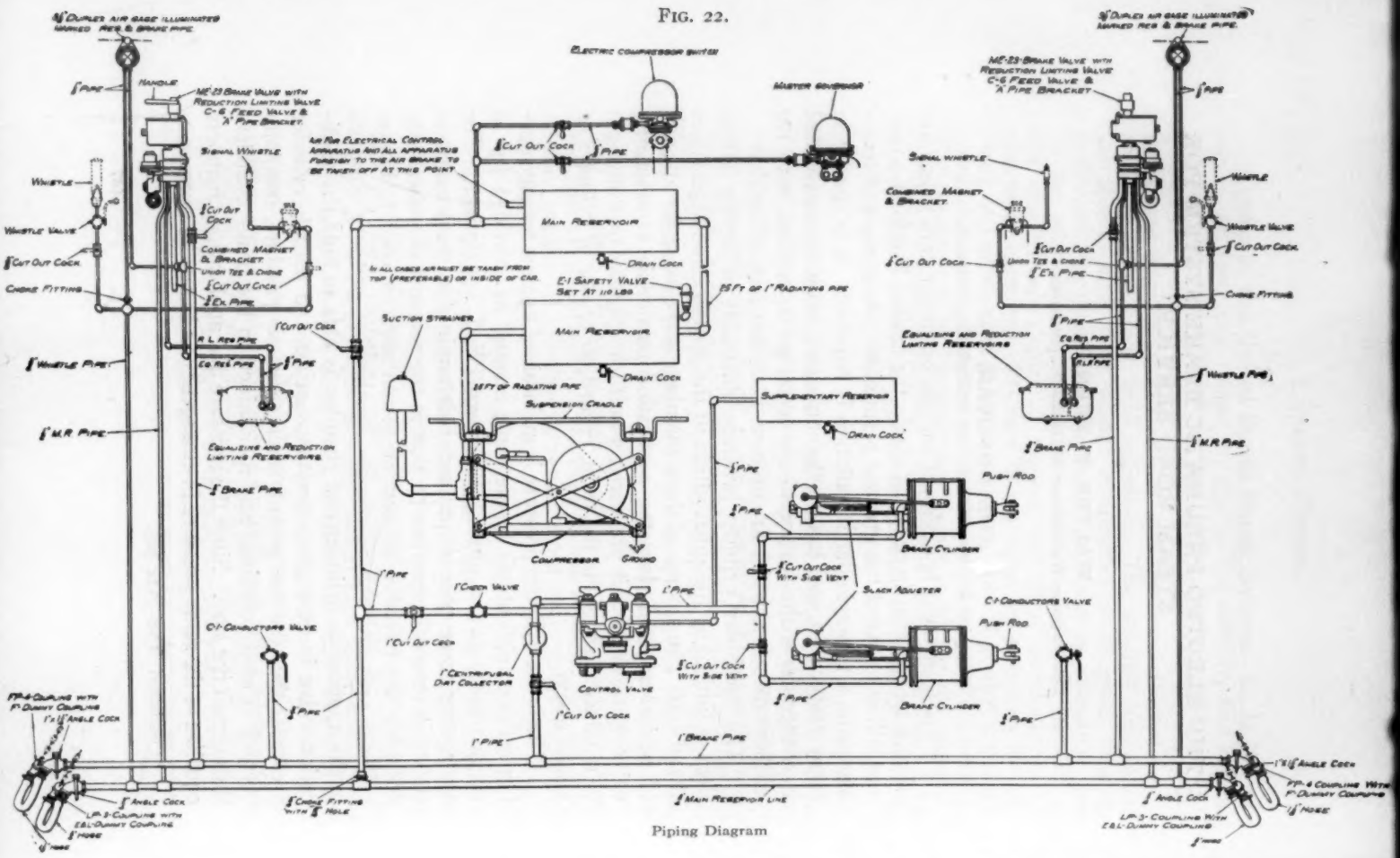
THIS equipment is designed for use on motor cars which are of such weight that in order to obtain the desired breaking power and still not exceed the greatest permissible pressures, and leverage ratio, a two-cylinder installation is required. It is similar in many respects to, and has all the important features enumerated in connection with, the previously-described equipment, with the addition of others which are necessary for this class of service.

The maximum cylinder pressure obtainable in service operations is limited by the equalization of the pressure and application chambers. The volume of these chambers is the same for all sizes of equipment, and since the application portion is a measuring valve, governed by air pressures, a uniform cylinder pressure will be obtained throughout the train, *regardless of size of cylinder or piston travel.*

The brake-cylinder pressure is maintained against leakage during service applications in the same manner as provided for in the distributing valve of the well-known " E. T." equipment. The emergency brake-cylinder pressure is determined by the pressure in the main reservoir, and not by that in the pressure chamber. By reducing the effective application piston area exposed to brake-cylinder pressure, the 50 pounds equalization pressure obtained in the application cylinder and chamber is able to hold the application valve in emergency position against 150 pounds cylinder pressure; thus the 100 pounds main reservoir pressure, normally carried, is easily obtained and maintained in the brake cylinders throughout the stop. Since the pressure and application chambers equalize at the same pressure in emergency as in service operation,

[1] Continued from page 325.

FIG. 22.



Piping Diagram

it follows that the brake-cylinder air can be easily released, because the brake-pipe pressure need only be raised a little higher than the pressure-chamber pressure in order to effect a release.

The pressure chamber is charged from the supplementary reservoir, when the graduated-release feature is operative, up to about five pounds less than normal brake-pipe pressure, so that practically no air is drawn from the brake pipe. This insures a prompt and certain release of the brakes and a rapid recharge and prompt response to successive reductions, which may be made because (1) the air delivered to the brake pipe is all effective in raising its pressure, and (2) the pressure chamber and brake pipe charge at the same rate. With the graduated-release feature inoperative, the supplementary reservoir is cut out, so that the above recharging does not take place, but, owing to the small volume of the pressure chamber, the release is still much more positive and certain than with the older equipments, and this is especially true in cases of long trains, where, with the old equipments, there are large volumes to charge, and, since their source of supply is the brake pipe, necessitates large feed grooves. This makes the rate of increase of brake-pipe pressure on the rear end very slow, since the reservoirs on the head end are taking the air from the brake pipe almost as rapidly as the brake valve can supply it.

Fig. 22 shows the piping diagram of this equipment, which pneumatically consists of a two-compartment reservoir, a supplementary reservoir, and several operating parts embodied in a control valve. These two compartments, the pressure and application chambers, correspond respectively to the auxiliary reservoir and the brake cylinder of the older types of brakes, except that the application-chamber pressure, instead of operating the foundation-brake rigging, actuates the application portion (which is really a measuring valve), and measures, from the main reservoir into the brake cylinders, sufficient air to make the pressure in the latter equal to that in the application chamber.

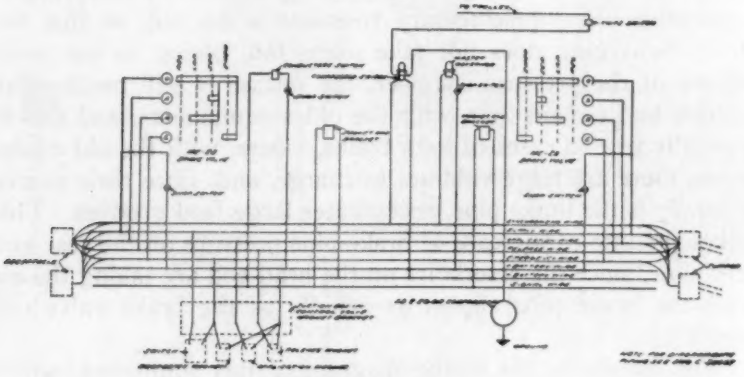
Fig. 23 shows the wiring diagram. Electrically, the equipment comprises the usual application and release magnets, with their attached valves, controlling the electric service application and release of the brakes. In addition to these, there is a third magnet, the emergency application magnet, with its valve, controlling the operation of the emergency parts of the control valve.

The emergency switch and piston might be called the connecting link between the pneumatic and the electric emergency functions of the equipment. It serves as a circuit-closer to produce electrical quick action throughout the train, when originating pneumatically.

The operating valve (Fig. 24) for this equipment is the same as that used in connection with the previously-described equipment.

The novel and distinctive features of this equipment are embodied in the control valve (Figs. 25 and 26), which is comprised of five portions.

FIG. 23.



Wiring Diagram

The Equalizing Portion, in which are: the equalizing piston, equalizing slide valve and graduating valve, which indirectly control the pneumatic service application and release of the brake (through the control of the application-chamber pressure) and the charging of the pressure chamber and supplementary reservoir; the equalizing cylinder cap, which has two positions, one for electric service and one for steam road service. In the latter position, the additional application chamber and the main reservoir charging check valve are rendered operative. The main reservoir charging check valve (operative only when the equalizing cylinder cap is set for steam road service) separates the brake pipe and main reservoir, allowing the former to charge the latter, and preventing a back flow of air from the main reservoir when a brake-pipe reduction is made; the direct- and graduated-release

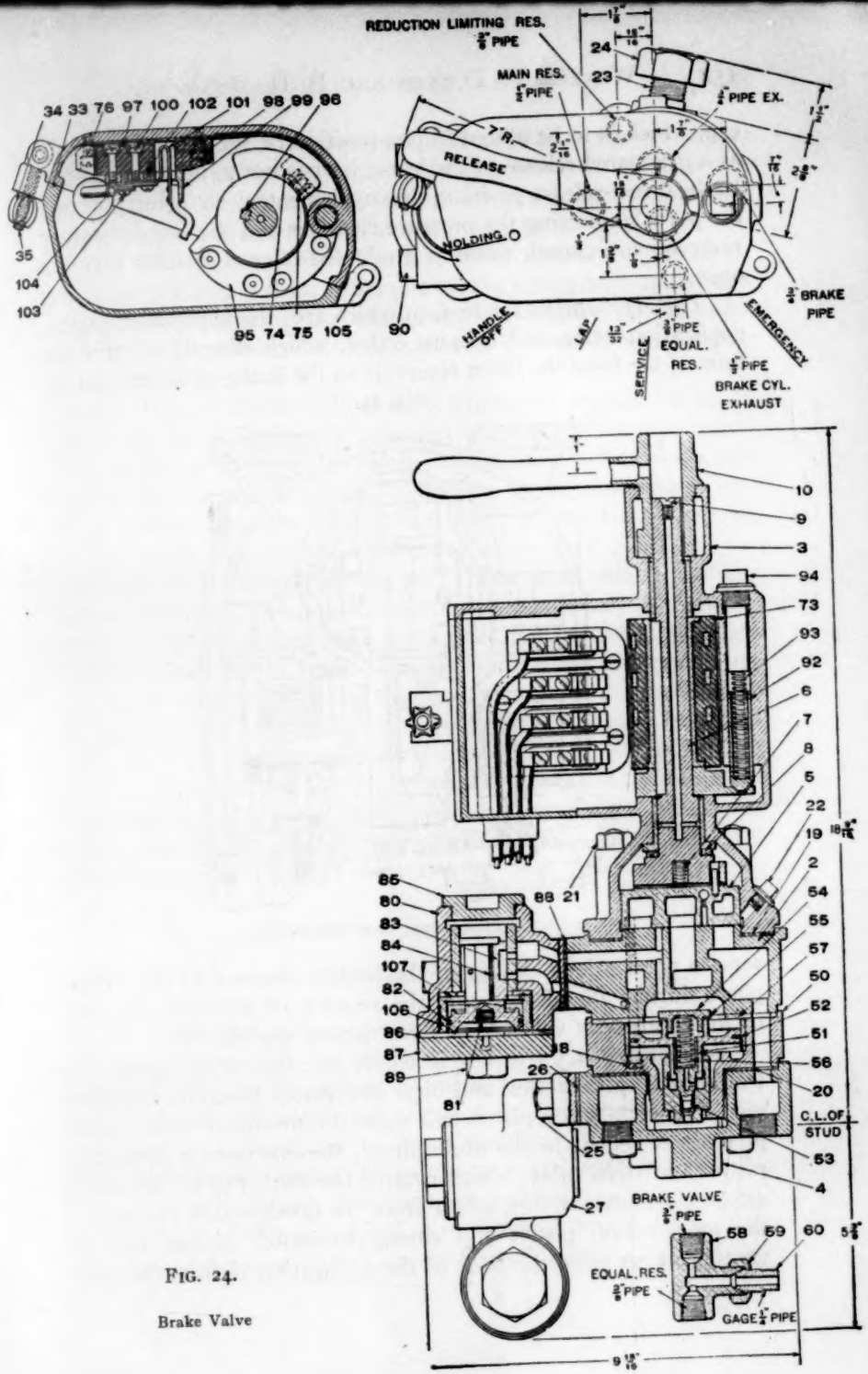


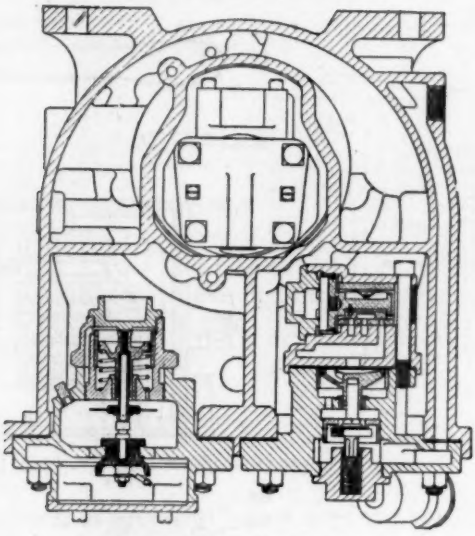
FIG. 24.

Brake Valve

cap, which is to be placed in one position or the other, according as a graduated release of the brake is or is not to be provided for. In the direct-release position, the supplementary charging port and the ports connecting the pressure chamber and the supplementary reservoir are closed, while in graduated-release position they are open.

The Application Portion, in which are: the application piston, application valve and exhaust valve, which directly control the flow of air from the main reservoir to the brake cylinders during

FIG. 25.



Control Valve. Cross Section.

service applications and from the brake cylinders to the atmosphere during all releases, and the venting of air from the back of the emergency valve during emergency applications.

The Emergency Portion, in which are: the various parts controlling the quick-action and high emergency pressure functions, viz., the quick-action piston and valve, by means of which brake-pipe air is vented to the atmosphere; the emergency slide-valve piston and slide valve, which control the charging of the quick-action chamber, the flow of air from the quick-action chamber to the quick-action piston and emergency-switch piston, and the venting of air from the back of the application piston; the emer-

gency valve, which, when open, permits main reservoir air to flow direct to the brake cylinders; the protection valve, which automatically produces quick action when the brake-pipe pressure is reduced to a certain predetermined value.

The Emergency Switch Portion, which consists of an emergency switch and piston, which closes the emergency application magnet circuit during an emergency application, at the same time that the quick-action valve is opened (by air from the quick-action chamber).

The Magnet Bracket Portion, in which are: the service application magnet and valve, by means of which the brake-pipe reduction is made at each car; the release magnet and valve, which control the electric release of the brakes; the emergency magnet and valve, which cause the quick-action parts to operate by venting air from the face of the emergency slide-valve piston to the atmosphere; the electric service port check valve, which prevents loss of brake-cylinder pressure during an emergency application, which would otherwise take place past the service application magnet valve into the brake pipe, and thence past the emergency application magnet valve and the protection valve exhausts to the atmosphere; the magnet valve cut-out cap, by means of which either or both of the application magnets may be cut out or cut in; a junction box, which permits of the wiring connections being easily and neatly made, and also greatly facilitates the making and breaking of these connections in inspection and maintenance work, as well as protecting them from damage.

OPERATION OF THE EQUIPMENT.

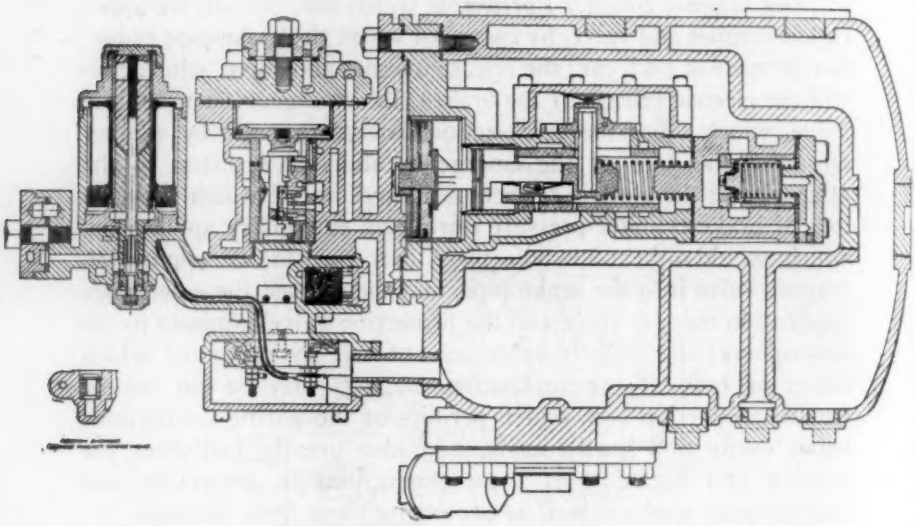
Charging Position.

Air from the brake pipe enters the valve as indicated on Fig. 27 and flows past the quick-action valve, which is seated, and then to the face of the protection valve, which will remain seated until a certain predetermined pressure is reached, when it will be moved very quickly to its closed position. Air then flows to the face of the emergency slide-valve piston, forcing it to release (if not already there), then through the feed groove into the chamber back of this piston and to the quick-action chamber. Air from the brake pipe is in communication with the service and

emergency magnet valves by way of the strainer and magnet cut-out cap (shown in normal position).

Brake-pipe air also flows to the face of the equalizing piston, forcing it with its valve to release position (if not already there). The chamber in front of the equalizing piston is in communication with the pressure chamber through two channels: first, by way of the feed groove and slide-valve chamber, and, second, direct, through the direct- and graduated-release cap.

FIG. 26.



Control Valve—Longitudinal Section

The supplementary reservoir is charged through the equalizing slide valve from the slide-valve chamber. The feed groove and the additional pressure chamber charging port (closed when the direct- and graduated-release cap is set for direct release) bear the same relation to the combined volumes of the pressure chamber and the supplementary reservoir as the feed groove does to the pressure chamber, consequently the time required to charge the equipment will be the same whether the supplementary reservoir is cut in or not.

Main reservoir air enters the valve as indicated and flows from the application valve chamber to the back of emergency valve, and also to the face of this valve, which will then be balanced and held seated by its spring.

ELECTRIC SERVICE APPLICATION.

When an electric application of the brakes is desired, the brake-valve handle is moved to the service application position, which is the same for both electric and pneumatic operation, but in passing from release position to service position, lap position is passed over, in which position the release magnet circuit is closed, energizing this magnet, which, in turn, seats the release magnet valve. This magnet valve is held closed in service position as well, and, in addition, the application magnet circuit is closed, energizing this magnet, which, in turn, opens the service application magnet valve. This allows brake-pipe air to flow past the electric service port check valve into the brake cylinder. The electric service application port is choked down to the proper size to permit of a rate of brake-pipe reduction which will cause the equalizing piston, graduating valve, and slide valve to move to service position. But this rate of reduction is not rapid enough to move the emergency slide-valve piston and its slide valve, since, under these conditions, the quick-action chamber pressure can reduce through its feed groove as rapidly as the brake-pipe pressure is being reduced. This insures the desired service application and prevents the possibility of undesired quick action.

The first movement of the equalizing piston and graduating valve toward service position closes the feed groove, the supplementary reservoir charging port, opens the service port, and allows the cavity in the graduating valve to connect the resistance increasing cavity to atmospheric pressure. This increase in the amount of the under surface of the slide valve, which is exposed to the atmosphere, increases the resistance which has to be overcome before the equalizing slide valve can be moved. This feature was explained fully in connection with the previously-described equipment (second instalment of paper).

The air flowing into the application cylinder from the pressure chamber will move the application piston to application position, carrying with it the application valve and exhaust valve. The exhaust valve closes the exhaust ports and prevents any flow of air from the exhaust-valve chamber and the brake cylinders to the atmosphere. The application valve opens the application port and allows main reservoir air to flow into the exhaust-valve chamber, and thence into the brake cylinders. The pressure in

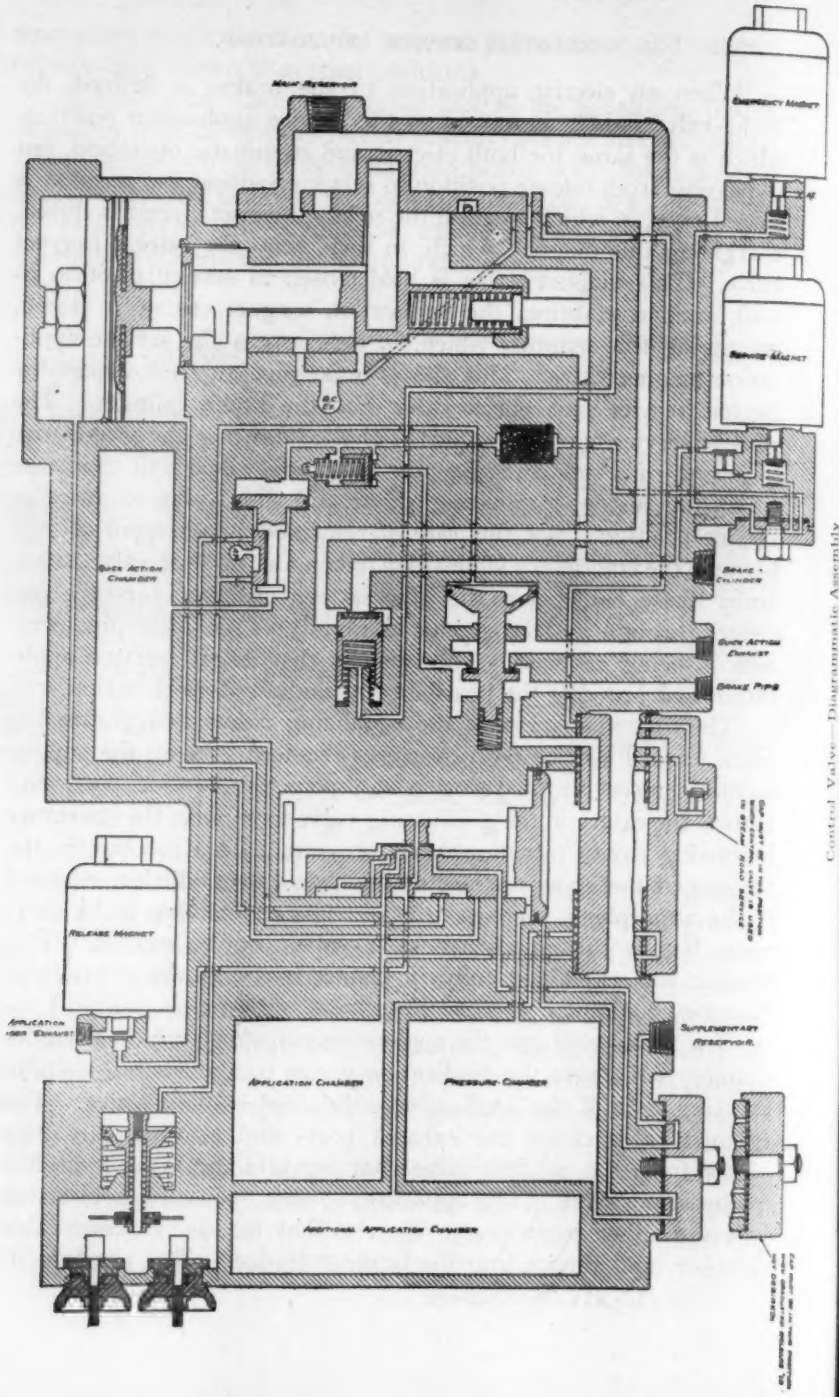


FIG. 27.

Control Valve—Diagrammatic Assembly

exhaust-valve chamber and in the chamber back of application piston are kept the same in service applications, since these chambers are connected by feed groove in small application piston bush.

The pressures in the application cylinder and chamber will be increased until they have equalized with the pressure chamber (the volumes of these chambers being so proportioned that with 70 pounds in the pressure chamber an equalization of 50 pounds is obtained), or (in case a full service reduction in brake-pipe pressure is not made) the pressure-chamber pressure is reduced to a point slightly lower than that in the brake pipe. In the latter case, the equalizing piston and graduating valve will be moved back from service position until the equalizing piston rests against the slide valve in service lap position, thus closing the service port, which prevents a further building up of application-cylinder pressure.

The flow of air from the main reservoir to the brake cylinders continues until the pressure in the brake cylinders, and consequently in the exhaust-valve chamber, is equal to that in the application cylinder, when the application piston graduating spring will move the piston and valve back to service lap position, in which position the application port is closed. The pressures on both sides of the application piston are balanced, and consequently if there be any drop in brake-cylinder pressure, due to leakage, the application piston will be moved toward the lower pressure, and cause a slight renewal of pressure in the exhaust-valve chamber and brake cylinders; thus the air lost from the brake cylinder by leakage is automatically replaced by this operation of the application piston and valve, and the brake-cylinder pressure maintained at an equality with that being held in the application cylinder. The lost motion between the application piston and the exhaust valve allows the application piston and valve to be moved back and forth in thus maintaining brake-cylinder pressure without moving the exhaust valve.

The service application magnet may be held energized, thus holding the magnet valve open and allowing the equalization of the pressure chamber with the application chamber and application cylinder (giving a full-service application of the brakes), or it may be energized for only a portion of the time necessary to cause a full-service application, and thus cause only a partial

application of the brake, after which the parts will be moved to service lap position, as above mentioned. The energizing of the service magnet may be repeated several times, each time causing a further increase in the brake-cylinder pressure, corresponding to the amount of brake-pipe reduction, until the final equalization of the pressure chamber and the application chamber and cylinder.

The application port is larger than the port leading from the exhaust-valve chamber to the brake cylinder. Therefore the former does not need a full opening to supply the latter, and, consequently, the application valve will never move past its service position far enough to allow the port in the application valve to connect the ports leading to the atmosphere and to the back of emergency valve (as is done in emergency).

ELECTRIC EMERGENCY APPLICATION.

With the brake-valve handle in emergency position, the emergency magnet circuit is closed, energizing this magnet, which, in turn, opens the emergency application magnet valve and allows brake-pipe air to flow through the emergency magnet valve port to the atmosphere. The emergency exhaust port of the brake valve is also open; but, since the electric current travels so much faster than the reduction of air pressures, it is the electrical emergency that controls and applies all the brakes in the train, practically simultaneously. The emergency magnet valve port is of such size as to permit of a rate of brake-pipe reduction which will cause the emergency slide-valve piston and its slide valve to move over to emergency position, and also cause the equalizing piston and its slide valve to move over until the piston rests against its cylinder cap gasket (in which position the same port openings prevail as in service application).

With the emergency slide-valve piston and slide valve in emergency position, the quick-action chamber air flows to the quick-action piston, thus forcing the quick-action valve open, thereby venting brake-pipe air to the atmosphere (which causes a sudden local brake-pipe reduction that starts pneumatic quick action), and to the emergency switch piston, thereby closing the emergency switch, which serves as a circuit-closer to cause instantaneous quick action throughout the train when originating pneumatically.

The quick-action valve will remain open and the emergency switch closed until the quick-action chamber air can drain to the atmosphere, through the small drilled port in the quick-action piston, after which they will be returned to their normal positions by their springs.

With pressure-chamber air flowing into the application chamber and cylinder, and the chamber back of the application piston connected to the atmosphere (by way of the equalizing slide valve, and the cavity in the emergency slide valve), the application piston will be moved over until the leather seal on its inner side rests against the seat on the end of the small bush. In this position the feed groove in the small bush has been cut off, thus separating the exhaust-valve chamber from the chamber back of the application piston. The application valve chamber and exhaust-valve chamber are connected through the application port, the same as in service, and, in addition to this, another port in the application valve connects the chamber back of the emergency valve to the atmosphere; thus the emergency valve, with main reservoir pressure on the face and atmospheric pressure on the back, will open and make a large direct connection between the main reservoir and the brake cylinders, and allow these pressures to equalize in a very short time. With the chamber back of application piston connected to the atmosphere, the application piston area exposed to application-chamber pressure is about three times that exposed to exhaust-valve chamber pressure, consequently the 50 pounds equalizing pressure of pressure and application chambers is able to retain a brake-cylinder pressure of 150 pounds, which would be more than the highest possible pressure in emergency, since the compressor governors are set to cut out at 100 pounds.

ELECTRIC RELEASE AFTER SERVICE APPLICATION.

With the brake-valve handle in release position, the release magnet circuit is open, de-energizing this magnet and allowing the release magnet valve to open. The brake-pipe port in the brake valve is also open, and is restoring the air in the brake pipe to its initial pressure. This increase in brake-pipe pressure forces the equalizing piston and its slide valve back to their release positions, in which the application-chamber and application-cylinder air is exhausted to the atmosphere by way of the equalizing

slide valve, graduating valve, and release magnet valve. With the air in application cylinder exhausting to the atmosphere, the higher brake-cylinder pressure in the exhaust-valve chamber (back of application piston) will force the application piston back from lap position to release, carrying with it the exhaust valve. The latter will open the exhaust port and allow the brake-cylinder air to flow to the atmosphere.

ELECTRIC RELEASE AFTER EMERGENCY APPLICATION.

After an emergency application has been made, the quick-action valve will remain open and the emergency switch closed until the quick-action chamber air has drained to the atmosphere through the small drilled port in the quick-action piston, after which the quick-action valve will be closed and the emergency switch opened by their respective springs.

With the quick-action valve closed and the brake-pipe pressure being restored, the protection valve will be the first to go to normal position (release), which will, in turn, admit air to the face of the emergency slide-valve piston, forcing it to release and charging the quick-action chamber as described under "Charging." Brake-pipe pressure has also been built up on the face of the equalizing piston, forcing it, with its valves, to release position, which will, in turn, permit the exhaust of application cylinder and chamber air and the return of the application piston and its valves to release position, and, finally, the emergency valve will be balanced by the opening of the ports leading to the back and to the front of this valve, and will be seated by its spring, closing the direct communication between the main reservoir and the brake cylinders, after which the high pressure brake-cylinder air will exhaust to the atmosphere.

GRADUATED RELEASE.

The release of the brakes may be graduated by moving the brake-valve handle to release for a few seconds and then back to lap position. The brake-pipe charging port of the brake valve is open in release position, causing a slight increase in the brake-pipe pressure and moving the equalizing parts of the control valve to release position. (In lap position of the brake valve the brake-pipe charging port is closed, consequently only a few pounds in-

crease in brake-pipe pressure will result.) Also in release position of the brake valve the release magnet circuit is de-energized and the release magnet valve is held open by its spring, thus allowing the air from the application chamber and cylinder to flow through ports in the equalizing slide valve, cavity in the graduating valve, and past the release magnet valve to the atmosphere. The application piston and valves will then be returned to release position, making connection from the brake cylinders to the atmosphere.

But with the equalizing parts in release position, and the direct and graduated release cap in the position marked "Graduated Release," the graduated release port is open and connects the supplementary reservoir and the pressure chamber; since the former volume is not used in service operations, it will still have its initial pressure. Supplementary reservoir air flowing back into the pressure chamber will quickly raise the pressure in the latter slightly in excess of that in the brake pipe, and, consequently, it will move the equalizing piston and graduating valve to graduated release lap position, in which the graduated-release port is closed, thus preventing a further increase in pressure-chamber pressure, and a further decrease of application cylinder and chamber pressure. Brake-cylinder air will continue to exhaust to the atmosphere until its pressure is slightly lower than that being held in the application cylinder, when the application piston and exhaust valve will be moved back to lap position.

A further reduction of brake-cylinder pressure cannot now be made until the brake-pipe pressure is further increased, and the equalizing piston and graduating valve moved to release position, when the above operation will be repeated. This graduation of the release may be repeated until the brake-pipe, pressure-chamber and supplementary reservoir pressures are equalized, when the valves will remain in release position and give the final release of brake-cylinder air.

Even with the direct- and graduated-release cap in "direct release" position (which closes the supplementary reservoir connection to the pressure chamber), it is always possible (when the electric features are operative) to graduate the release of the brake by means of the release magnet valve alone, if the brake-valve handle is moved alternately to release position and back to lap (the equalizing parts of the control valve remaining in release position).

PNEUMATIC OPERATION.

In case any of the electric features should be inoperative, through loss of current or other causes, the equipment may be operated as any of the older types, the brake-pipe reductions then being made by means of the brake valve alone (the positions of the brake valve handle being the same for both electric and pneumatic operation).

PNEUMATIC SERVICE APPLICATION.

With the brake-valve handle in service position, the preliminary exhaust port in the brake valve is opened, allowing the equalizing piston to lift and produce a rate of brake-pipe reduction sufficiently rapid to move the equalizing piston, graduating and slide valves to service position. The rate of reduction as fixed by the brake valve is, however, not as rapid as that at which the quick-action chamber pressure can be reduced through its feed groove into the brake pipe (thus positively guarding against undesired quick action).

The operation of the various valves is now the same as previously described under " Electric service application."

PNEUMATIC EMERGENCY APPLICATION.

With brake-valve handle in this position, the emergency exhaust port is open and permits of such a rapid rate of brake-pipe reduction that the quick-action chamber pressure cannot reduce as rapidly through its feed groove as the brake-pipe pressure is being reduced through the brake valve. Consequently, the emergency piston and its slide valve are moved to their emergency positions. The equalizing piston has also moved (carrying with it the slide valve and graduating valve) against the cylinder-cap gasket.

The operation of the various valves is now the same as previously described under " Electric Emergency Application."

PNEUMATIC GRADUATED RELEASE.

This is accomplished in the same manner as previously described, except that the release magnet valve is open at all times, and the graduated release controlled entirely by the pneumatic parts.

PROTECTION FEATURE.

In case there is excessive leakage, after a full-service application has been made, which will reduce the break-pipe pressure to a certain predetermined value the protection valve will be forced open by its spring, thus connecting the face of the emergency slide-valve piston to the atmosphere, past the protection valve seat, and producing a rate of brake-pipe reduction that will cause the emergency piston and slide valve to move to emergency position, thus causing quick action as previously described.

STEAM ROAD SERVICE.

Cars having this equipment may at times be used in steam road trains in connection with standard steam road cars, upon which the braking power is calculated on the old basis of 90 per cent. on 60 pounds cylinder pressure (equivalent to 75 per cent. on 50 pounds), consequently cars with E-11 control valve, having their braking power calculated on the basis of 100 per cent. for 50 pounds cylinder pressure, some means must be used whereby this difference may be eliminated, or at least reduced considerably, if the desired uniformity in service-brake operation is to be obtained.

This is accomplished by using, in such cases, an additional application chamber, thus increasing the volume of the application chamber so that from 110 pounds pressure carried (which is used in almost all steam road passenger service) the pressure and application chambers will equalize at 70 pounds.

This means that a lower brake-cylinder pressure, and, consequently, less braking power, is obtained for a given brake-pipe reduction. As a matter of fact, the control valve equipment under these circumstances actually obtains ¼ of 1 per cent. less braking power per pound of brake-pipe reduction than the ordinary automatic brake in general use in steam railway service, and 5 per cent. for a full-service brake-pipe reduction (20 pounds), the steam car thus having the higher braking power.

In emergency operation, the E-11 equipment car set for steam road service will obtain a little above 200 per cent. braking power and retain it throughout the stop, while the steam road car will obtain 127 per cent., and which will gradually be reduced to 90 per cent. as the car is retarded, due to the action of the high-speed reducing valves.

This inequality can be tolerated in emergency, because then "to stop" is the most important factor.

When a car equipped with this valve is used in steam road service (for example, when being transported from the manufacturer to its destination) the equalizing cylinder cap must be turned to the proper position for this service. In this position the ports are so connected that when a brake application is made air flowing from the pressure chamber into the application chamber and cylinder can also flow into the additional application chamber. This extra volume added to the application chamber increases its volume to such an extent that now, with the pressure chamber charged to 110 pounds, the pressure-chamber pressure will equalize into the application chamber and cylinder at 70 pounds; thus the service cylinder pressure is limited to 70 pounds, and the emergency-cylinder pressure to something less than 110 pounds, which is the brake-pipe pressure carried and the maximum obtainable in the main reservoir; therefore the cylinder pressure cannot be built up high enough to give excessive braking power.

Again, in steam road service, we have no main reservoir line to supply air for braking this car; therefore, the main reservoir on this car will be charged from the brake pipe. Air from the brake pipe flowing to the face of equalizing piston is now free to flow past the main reservoir charging check valve and thence to the application-valve chamber and to the main reservoir. This reservoir charging port is of such size that the main reservoir in charging cannot take the air from the brake pipe fast enough to affect the brake operations; and since it separates the brake pipe from the main reservoir, in all except release position, the valve must be in the latter position before the reservoir can be charged.

Since in steam road service there is no means of obtaining electric current for the electric operation of the brake, it will be evident that under these conditions the equipment will be operated pneumatically.

(*To be continued.*)

Cerium. ANON. (*Brass World,* viii, 8, 294.)—Metallic cerium is a white metal resembling iron in color and tin in hardness. It can be readily rolled into sheet or drawn into wire. Its specific gravity is 6.92, or about that of zinc. It melts at 635° C., or practically at the same temperature as aluminum.

NOTES FROM THE U. S. BUREAU OF STANDARDS.

ON A MODIFIED FORM OF STABILITY TEST FOR SMOKELESS POWDER AND SIMILAR MATERIALS.[1]

By H. C. P. Weber,
Assistant Chemist, Bureau of Standards.

THE stability test is a form of the so-called explosion test. In the German test the sample is heated to 135° C. and the length of time is noted until the sample explodes. In the other form of high temperature test the temperature of the sample is gradually raised until a point is reached at which the sample explodes, or at least decomposes with explosive violence.

The decomposition of products of this class is exothermic and autocatalytic, and the temperature of the decomposing material may be few or many degrees removed from the temperature of the heating bath. The amount of this difference will depend on a number of variables, such as the mass of the material, its heat conductivity, and the heat conductivity of the systems used for test. These factors enter into the German 135° test as well as into the ordinary high temperature explosion test. In the former the time will vary with the heat insulation; in the latter the explosion temperature will vary with the rate of heating.

The proposed test consists in the determination of a time temperature explosion curve. The samples are chosen small enough to practically eliminate the factor of heat conductivity of the sample. The apparatus consists of a heating bath which may be kept at various constant temperatures. For this work the temperatures chosen were 200° C., 180° C., 170° C., 160° C. The length of time necessary for a sample to explode is determined with the aid of a stop-watch at one constant temperature, and then at the next, and so on. The results are plotted in a curve with time and temperature as ordinates and abscissæ.

That the results are reproducible to within a few per cent. is shown by numerous repetitions. After the curve has been plotted by means of three or four points, determinations made at intermediate temperatures fall on the curve. The curve is, there-

[1] Abstract of paper to appear in the Bulletin of the Bureau of Standards.

fore, characteristic of the sample. It represents, in effect, the rate of change of decomposition velocity with change of temperature, and as such is an index of the stability of the powder.

Inspection of the curves shows that for stable powders there is a pronounced bend, while the ratio of explosion periods at 200° C. and 160° C. is at least 2 : 9. In the unstable powders this ratio falls as low as 2 : 3 and the irregularities become greater. It also becomes evident that one explosion temperature, even if time is considered, does not give much information.

It is possible that with sufficient accumulated data the test may throw some light on the actual effect of a stabilizer on the natural decomposition velocity of powders.

A short résumé of the literature on stability tests is given.

THE ATOMIC WEIGHT OF BROMINE.[1]

By H. C. P. Weber.

THE National Bureau of Standards has just sent to press the results of the work of H. C. P. Weber on "A New Determination of Atomic Weight of Bromine." A considerable amount of work has been done in order to determine the atomic weight of bromine, and the oft-repeated comparison of the atomic weights of silver and bromine makes it seem that this ratio is known with considerable accuracy. The value accepted for bromine, however, rests almost entirely upon that of silver, and it is of interest and importance to obtain a ratio between it and some other element. For chlorine a number of determinations of the ratio of hydrogen to chlorine in hydrochloric acid have been made, both by purely physical and by chemical methods. For bromine similar comparisons have not been made. Since the determination of the ratio chlorine : hydrogen was carried out with reasonable ease it seemed probable that the method might be advantageously applied for the purpose of determining the ratio between hydrogen and bromine.

The ratio of the atomic weights of hydrogen and of bromine is obtained by determining the amount of bromine which a weighed quantity of hydrogen will remove from potassium brom-

[1] Abstract of forthcoming scientific paper to appear in vol. 9 of the Bulletin of the Bureau of Standards.

platinate. The hydrobromic acid formed is also weighed. From ten determinations twenty values are obtained giving the ratio H : Br equal to 1 : 79.306[6] with a probable error of ± .0014. Taking the atomic weight of hydrogen as 1.00779 (O = 16) the atomic weight of bromine is *79.924*.

THE TESTING AND PROPERTIES OF ELECTRIC CONDENSERS.[1]

IN the testing of condensers over a period of years much information has been collected, only a part of which is at present available to the public. Also, a large amount of work has been done elsewhere, which has appeared in various publications. It is the purpose of this circular to collect together the important facts concerning condensers and to present them as a connected whole. The different kinds of condensers are described, their properties discussed, and the most satisfactory methods of testing indicated.

On account of their importance as standards, mica condensers are treated at considerable length. The effect of absorption on the phase angle and effective capacity is discussed in considerable detail, and many results are given showing the values that may be expected for good mica condensers. Also, a standard method of test is indicated.

Paper condensers are similar in their behavior to mica condensers, but the effect of absorption is much more marked. Also, in some paper condensers the resistance of the plates affects the phase angle in a very pronounced manner. Results on a number of commercial condensers are given.

A TUBULAR ELECTRODYNAMOMETER FOR HEAVY CURRENTS.[2]

By P. G. Agnew.

THE field "coil" of the instrument consists of two coaxial copper tubes, thus giving a circular magnetic field in the space between the tubes. On direct current the distribution of the current is assumed to be uniform over the cross section of the tubes, but on alternating current, as is well known, the current

[1] Abstract of Circular of the Bureau of Standards, No. 36, 1912.

[2] Abstract of paper to appear in the Bulletin of the Bureau of Standards, vol. 9.

is crowded toward the outside of the inside tube and toward the inside of the outside tube, and the amount of this change of distribution depends upon the frequency. But if we have axial symmetry the magnetic field at any point is independent of the current distribution. For there is no magnetic field between the tubes due to the outside tube, and the field at any point due to the current in the inside tube symmetrically distributed about the axis depends only on the distance of the point from the axis, and, therefore, the total effect is independent of the distribution of current, so long as it is symmetrical with respect to the axis.

There are two moving coils astatically placed between the tubes, one above and one below the inner tube, and suspended by a phosphor bronze strip. The common axis of the tubes is placed in a horizontal position in order to permit the use of a vertical suspension. While the distribution of the current is not the same on alternating as on direct current, the magnetic field in the space between the tubes, and hence the torque, is the same.

By passing water through the inner tube, the instrument will carry continuously 5000 ampères, and without water cooling, 1200 ampères. The current-carrying capacity of the moving coils is 0.6 ampère.

Difficulties were at first encountered, due to distortion of the inside tube by differential thermal expansion and by magnetic impurities in the moving coil, but these were finally overcome.

It is of first importance to determine whether the instrument is affected by residual distribution errors. It has been found that a purely electrical test could be used for the exact centring of the inside tube, so that any such residual errors due to imperfections of workmanship could be removed.

At commercial frequencies no error whatever could be detected, due to eddy currents being set up in the tubes by the current in the moving coils.

Measurements of large currents by means of a current transformer whose ratio had been carefully determined were in substantial agreement with the indications of the tubular dynamometer. It is believed that the instrument is accurate to 0.05 per cent.

FRANKLIN INSTITUTE

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, September 4, 1912.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 4, 1912.

MR. WILFRED LEWIS *in the Chair.*

The following report was presented for first reading:
No. 2513.—McKee's Printing Plate and Process.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

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Mr. John T. Kille, 1822 Green Street, Philadelphia, Pa.
Mr. A. J. Lamborn, 1601 Real Estate Trust Building, Philadelphia, Pa.
Mr. Thomas S. Parvin, 1435 South Broad Street, Philadelphia, Pa.

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Essentials of Physics for college students. A text-book for undergraduates and a lecture course and reference work for teachers and other students of physics. By Daniel W. Hering, C.E., Ph.D., LL.D., Dean of the Faculty of the Graduate School and Professor of Physics in New York University. 353 pages, illustrations, 8vo. New York, D. Van Nostrand Company, 1912. Price $1.75.

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CURRENT TOPICS

Twenty Years' Progress in the Use of Acetylene. V. B. LEWES. (*Times Eng. Supple.*, July 3, 1912.)—Large quantities of acetylene can be safely stored in steel cylinders filled with porous briquettes soaked with acetone and then charged with acetylene under pressure. This dissolved acetylene is largely used on the European continent for railway lighting, and it has many advantages over other illuminants for lighting motor vehicles, for buoys, and for coastal lights. One important development is the use of acetylene in oxy-acetylene burners for autogenous welding; and another application, which promises to considerably increase the demand, is the use of acetylene in self-starting devices for motor vehicles.

Chemical Compounds of Radioactive Elements. H. SCHRADER. (*Phil. Mag.*, xxiv, 125.)—If actinium B is deposited on a platinum wire and the wire heated in a high vacuum (0.003 mm. of air), the radioactive deposit is volatilized at between 600° and 900° C. The volatility of the deposit is increased by previous treatment with chlorine, bromine, hydro-bromic acid, and hydriodic acid. The B and C products of the active deposits of radium, thorium, and actinium condense in air at a temperature several hundred degrees higher than they will in hydrogen. These differences are considered to be due to the formation of chemical compounds.

Cleaning Evaporator Tubes. L. W. THURLOW. (*Intern. Sugar Jour.*, xiv, 328.)—At present there is much lack of system in the selection of suitable means for removing scale from the evaporator tubes of multiple-effect apparatus used in cane-sugar factories. When the scale consists chiefly of calcium oxalate, sulphate, and carbonate, it is of little use applying sodium hydrate (caustic soda), as the surface of the incrustation remains quite hard. Hydrochloric acid alone has but little effect, as this only slightly disintegrates the surface. The most effective means is to treat first with a boiling solution of sodium carbonate, and then with dilute hydrochloric acid. The sodium carbonate should be a 3 per cent. solution, and the hydrochloric acid 1 per cent. Fill the evaporator with a 3 per cent. solution of sodium carbonate and raise the temperature to the boiling point, without a vacuum, as a high temperature is desirable. Every half hour titrate a sample of the evaporator's contents against standard acid, and continue the boiling until the figures are constant; the transformation from oxalate and sulphate into carbonate is then complete. Now run off the liquid in the evaporator, fill it up again with water, and

then add the 1 per cent. solution of hydrochloric acid. Heat to boiling and again titrate against standard alkali. The reaction is generally complete within one hour.

Nitrogen in Metals. ANON. (*Brass World,* viii, 8, 270.)—Only recently has the presence of nitrogen in metals been recognized, owing to the difficulty of detecting it by chemical analysis, but it is now known that some metals occlude it eagerly. Its effect on steel has been studied, and it has been shown to lower the strength of aluminum. Pure tantalum has an electrical resistance of 65 ohms, but after heating for one minute in an atmosphere of nitrogen under a slight pressure the resistance is increased to 240 ohms. The filament incandesces with equal brilliancy, and on account of the increased resistance a thicker filament can be used. It is probable that a tantalum nitride is formed during the heating.

The Inventor, the Public, and the Law. W. F. ROGERS. (*J. Ind. Eng. Chem.,* iv, 320.)—The United States patent system was framed with the object of encouraging and securing an early disclosure of an invention. The invention is the creation of the individual, and he had always the right to use it himself, or to work it secretly, or to allow the idea to be lost. In return for the disclosure, and for that alone, the State gives him the right to prevent others from working or using the invention for a limited period. By means of the disclosure other inventors are stimulated and enabled to improve on the invention, and the invention becomes available to the public when the patent expires. There is no duty on the patentee to work the invention which he has disclosed, and the proposals in a bill now before Congress providing for compulsory licenses would infringe upon the property rights of patentees as repeatedly laid down by the courts. These provisions are aimed at the large combines which refuse to work some of the patents they hold, but the requirements of the law could be easily met by them, and these requirements would be burdensome to the independent patentees. The present system has secured the establishment of numerous independent factories, but the proposed system would tend to concentrate the useful inventions into fewer hands. The Patent Bar believes that the complaints of the average inventor could be met by modifying the practice of the courts so as to reduce litigation, by empowering some single court to give a final decision covering the whole of the nine circuits, by ensuring that damages for infringement are commensurate with the loss inflicted, by making the information obtained by the Patent Office available to the public, and by modifying the intricate practice in "interference motions."

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